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Noise Landing Charges and Passengers' Choice of Airport

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Noise Landing Charges and Passengers' Choice of Airport

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This study demonstrates how aircraft noise can be translated into a form of landing charge. The objectives of the thesis were to develop noise landing charges for six of the major airports in England and to determine what the implication it has on passengers' choice of airports. An airport choice model is developed distinguished by three market types: long-haul international scheduled, short-haul international scheduled and charter international. Modelling of airport choice was also carried out for passengers from the Greater London and South East areas.

The best results are obtained using difference in access time, logarithmic difference in frequencies and weighted differences in fare variables. There is consistency in the access time coefficients for all three markets. Airport choice for international scheduled and charter passengers for the Greater London and other South East areas also show consistency in access time amongst different passenger groups in choosing airports.

The implication of the noise charge particularly at Gatwick and Heathrow for the short and long haul markets reveal that the fare coefficients are sensitive and are subject to doubt. However Brooke et al (1994) acknowledge that exact fare details are difficult to obtain. Therefore it is a difficult task to produce accurate fare coefficients with published fare details that do not take into account discounts received by passengers. This is reflected in this study by observing the fact that high number of passengers change airports, when it may be argued that the noise charges are moderate.

The sensitivity of the implications of the noise charge determined in this study have depended highly on the fare coefficients. This study has demonstrated the importance and perhaps the over reliance of depending on a single parameter for the evaluation of the implications of the noise charge.

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INTRODUCTION

1.1 Introduction

Liberalisation of the air transport industry has led to the role of airports to change dramatically. From being regarded as mere providers of infrastructure for airlines, they are now seen as commercial entities in their own right making significant contribution to regional economic growth and development. Although there remains controversy to some degree on understanding to a fuller extent the economics of airport development, as de Neufville says ‘it is almost an article of faith amongst airport planners that airports significantly affect economic growth.” This may be justified as it can be extremely difficult to disentangle the impact of airport operations on the local economy from the myriad of other influences on local activities. However a recent study of the industry in Western Europe (SRI International, 1990) found that economic activity attributable to the provision of commercial aviation approaches $75 billion annually, while providing 2.5 million jobs. Whether airports contribute to the economic growth of regions or not can be disputed, however the role of airports to provide the infrastructure for aviation activities to function is indisputable.

In an attempt to understand more precisely the significance of airport policies on regional growth, a considerable body of literature has emerged in this field (Kasper; Hermsen, 1991 and Hazel et al, 1991). To support this Airports Association Council International (AACI) Europe (1992) is in the process of developing a methodology to guide airports in monitoring their own economic impacts. However, while airports seek to strengthen their financial and economic base an emerging issue gaining substantial attention from the air transport industry is that of environmental pollution of airport operations.

Increased media attention, activities from environmental pressure groups have led to increased awareness of the pollution issue. Pollutions take the form of noise, emissions and fuel efficiency, congestion, waste of energy, water and materials. Of all the pollutants of airport activities, aircraft noise is consistently ranked as the primary one (Airport Support, 1988). At a number of recent conferences some organised by the European Community Bureau of the ICAA (1990), speaker after speaker made the point that noise at major European airports had reached a level where it was beginning to affect operations. "Aircraft noise continues to be a major constraint on the development of civil aviation. Because of public opposition to aircraft noise, airport expansion and construction are severely limited, and aircraft operations are being increasingly restricted, particularly at night". This statement had been expressed by the Airports Association Coordinating Council at the 27th session of the ICAO assembly in October 1989.

It is now acknowledged that reasonable trade-offs are required between the economic benefits of airports and the potential negative impacts. There are attempts by airlines and airports to convince the consumers, that what is good for the environment can also necessarily be good for the industry. It is not suggested that aircraft noise is good for the environment, however this study demonstrates how aircraft noise can be translated into a form of landing charge. Airport managers increasingly find themselves faced with rise in demand of airport use by airlines, at the same time residents of local communities demand solutions to noise. Thus effective management requires strategies that balance the needs of airport owners, airlines and their passengers and airport neighbours. This form of landing charge could be a means of a balanced noise management strategy.

1.2 Study Background

The development of air transport has produced both economic and social benefits to large numbers of people. However it also pollutes the environment in which it operates. Evidence suggests the quality of life of those exposed to the various types of pollution can be worsened rather than improved. Of the environmental factors that are commonly associated with pollution from air transport, noise is the most commonly cited of all. The reasons are obvious; noise from aircraft is easily detected by the human hearing system. Its effects can be cumulative and it influences our daily lives. It penetrates the work environment, particularly those living near the vicinity of airports, causing disturbance and interruption in concentration and vigilance. It disturbs people at home during leisure periods, to the extent that sleep provides no escape. Those who are able to sleep seemingly undisturbed by external noise, its presence may well reduce the quality of sleep without the subject being consciously aware of the fact (Nelson, 1987).

1.2.1 Airport Noise

Airports contribute to the economic development of communities. Often, they influence the location of new businesses and industry, and also stimulate employment opportunities. Despite the many positive elements, aircraft noise is recognised as the primary negative impact to residential communities around airports (Bragdon, 1987).

Examination of recent airport movement statistics world-wide shows that trade-offs between increased utilisation of airport resources and higher levels of annoyance, due to aircraft noise is becoming a crucial aspect of airport management (Gillen, Levesque and Smith, 1990). The perceived distribution of benefits and costs of increased airport use involves two relatively different groups. Airport residential neighbours typically do not see themselves as the beneficiaries when a runway is added or a late night flight is instituted while most of the direct beneficiaries, the flying public are not so geographically concentrated. The UK Department of Transport consultation paper for night flights at Heathrow, Gatwick and Stansted airports, (proposals for revised restrictions from 24 October 1993) provides evidence that members of local communities around these airports have argued not only for limited restrictions but a total ban on all flights at night time operations. Similar arguments exist for other airports in the US and Europe (ICAA Seminar on aircraft noise and air pollution, 1990). Therefore it can be seen that reconciliation between these two groups is a key factor for successful operation of the modern airport.

There has been no fundamentally new noise control technology developed since the turbofan entered service. Improvement over the past twenty years has only come from manufacturing industry refining its use of established control techniques. This has made aircraft a little quieter at constant weight, or no noisier as aircraft size has increased but, for the time being there is no high expectations from technological solutions (Smith, 1991).

All the various long term forecasts produced in recent years indicate that passenger traffic world-wide would double within the next 10-15 years. This projected increase in passenger traffic, is providing the impetus for accelerated airport developments in terms of more runways, terminal capacity, and the utilisation of technology to improve airport airspace capacity. However at the same time, there is clear evidence showing that airport neighbours increasingly oppose capacity expansion plans to contain noise exposure. Hence, if the air transport industries are to meet this increase in demand for air travel, determined efforts are required to reduce the burden of noise upon these communities. Policies should reflect optimum balance between resource utilisation and environmental protection. The development of a noise management strategy is required, that balances the needs of airport owners, airlines and their passengers and residents of local communities.

1.2.2 Present State of Noise Management

Alleviation of aircraft noise is a major technological challenge for air transportation. There is no one comprehensive plan devised which encompasses state, local governments and other segments of aviation industry to alleviate the noise problem. No one particular organisation has taken the overall responsibility for the problem, as indeed the political, legal, economic and technical factors which are an inherent part of the problem prevent any one group taking overall responsibility for a plan to be formulated and implemented.

Noise management strategies are used at airports in Canada, USA, Europe, Japan and member states of ICAO. Noise control, abatement and exposure plans vary from country to country and within a country from airport to airport. To illustrate the complexity of noise management Cline (1986), showed that four hundred airports in the US alone operate thirty seven categories of noise control strategies.

Various international bodies such as International Civil Aviation Organisation (ICAO) in Europe and Federal Aviation Regulations (FAR) in the US, derive regulatory policies to contain airport noise. Some airports use only these international standards set by the organisations, while other airports introduce additional local policies to deal with the noise. ICAO at present is considering the introduction of a more stringent criterion of regulatory standards that go beyond the current Chapter III noise legislations (Avmark, 1995). Analysts point out if this is enforced as a new legislation, the effect on the air transport industry could be detrimental.

Figure 1.1 shows a block schematic diagram of an aircraft noise control model. Any one technique such as operational restrictions or a combination of all them are used at various airports to contain noise. Noise charges are one of the remaining methods not yet fully explored nor implemented at all airports. However predictions of future scenarios indicate that noise charges are becoming more widespread to reflect growing environmental concerns (Carter 1991).

NOISE CONTROL MODEL

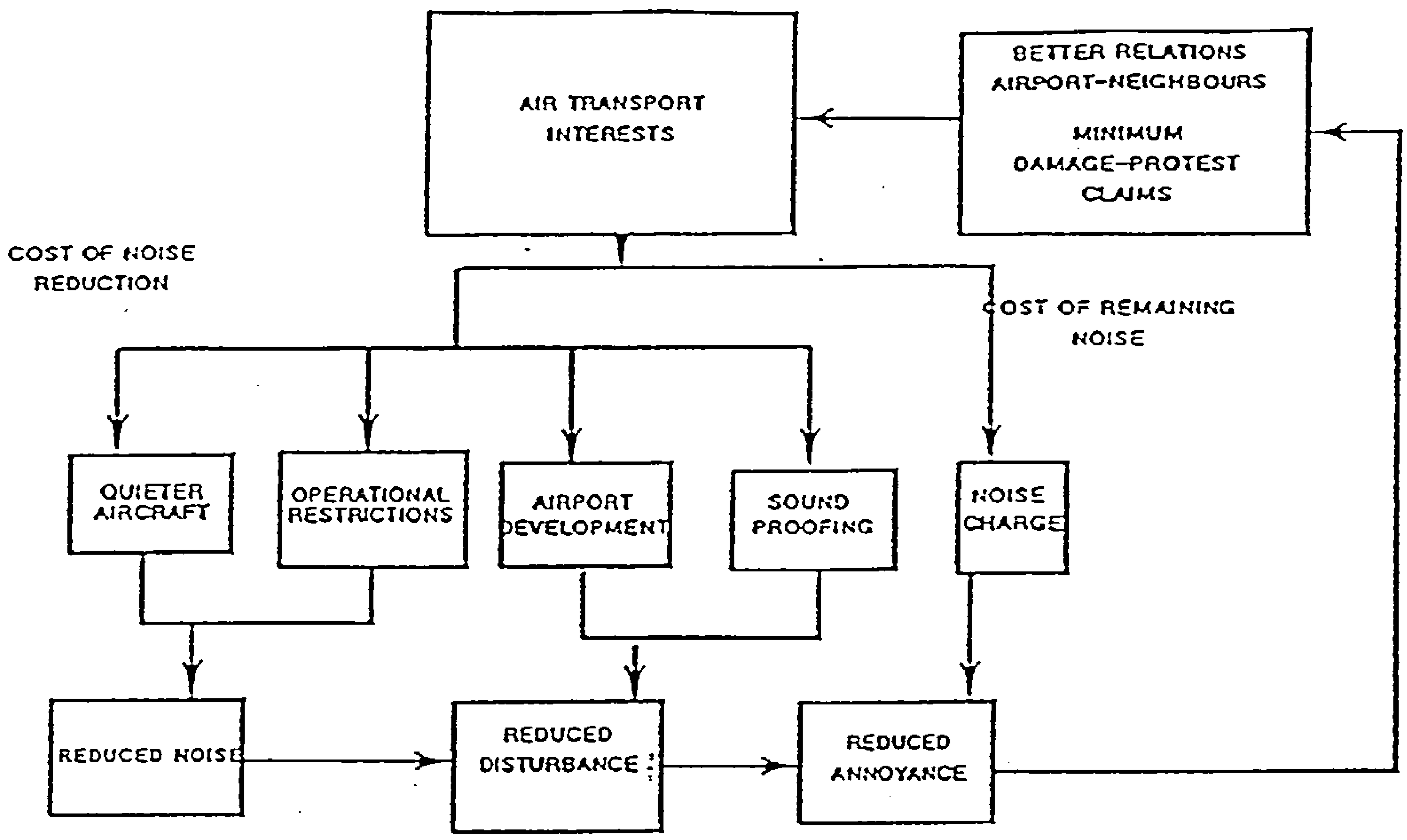


Fig 1.1, Source: Ollerhead, 1973

1.2.3 Airport, Airline and Passenger Behavioural Model

Figure 1.2 presents a model showing the relationship between airport, airlines and their passengers.

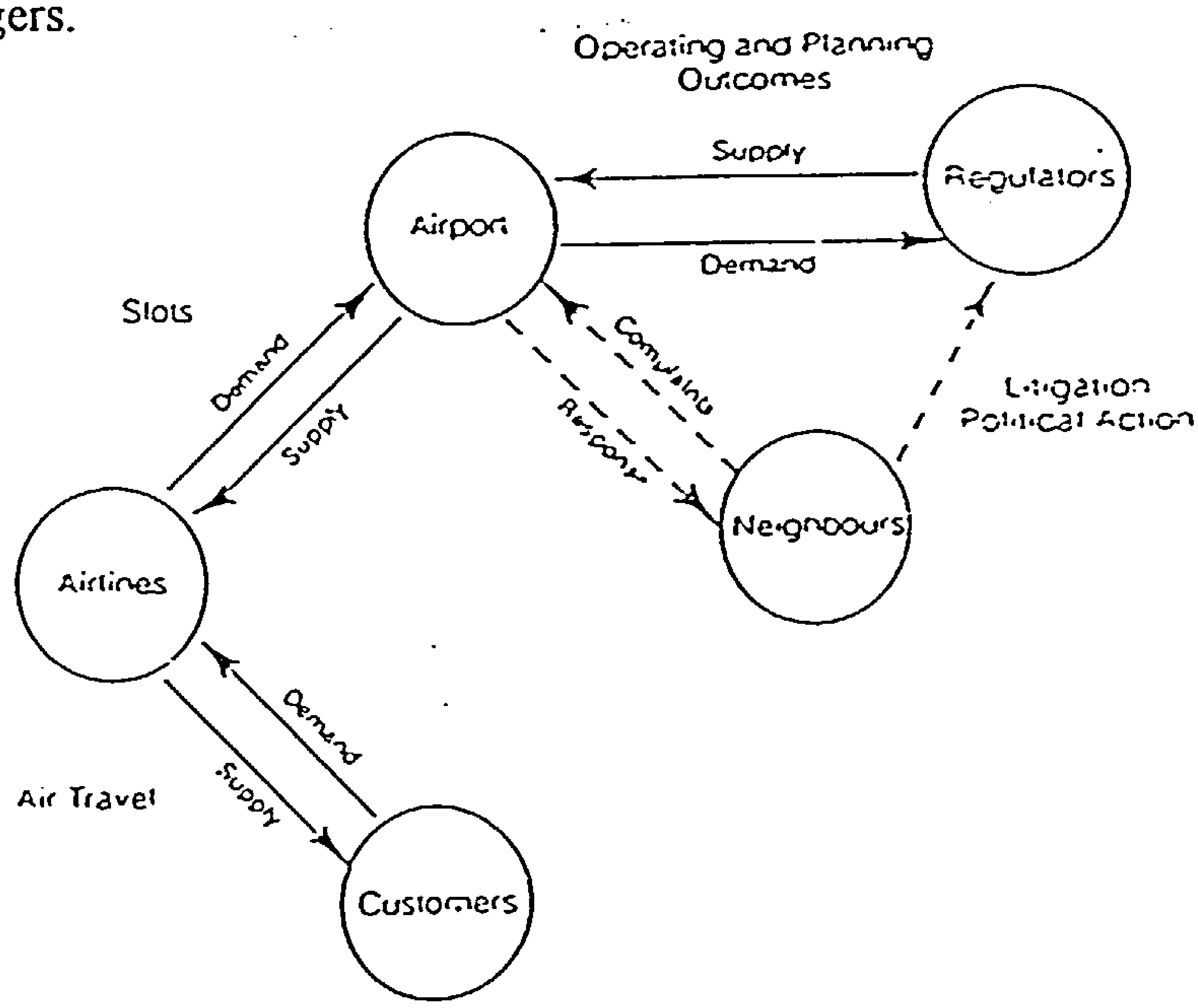


Fig 1.2, Source: Gillen et al, 1990

The level of noise at airports depends on the level of interaction between airlines and their customers in the air travel market, and the interaction between airlines and airports in their access for slots. Noise increases as either of the two activities increase. Noise management strategies that impose costs onto passengers will affect their demand. An airport for example, may raise airlines' costs of using airport facilities if it requires that carriers upgrade fleets to Stage III standards from Stage II as is the case at a number of European and US airports. It also raises air carriers costs if it taxes to support noise abatement, or if it fines them for noise violations.

The likely response of carriers to such operating cost increases would either be to pass on the cost directly to passengers, or to reschedule their services to an alternative lower cost airport. The response of airlines will depend on how easy or difficult it is to pass on the extra costs to passengers. Table 1.1 summarises how the airlines are likely to respond to avoid costs imposed by noise management strategies.

	Availability of lower-cost airports	Non Availability of lower-cost airports
Easy to pass costs to passengers	Stay, pass on costs, threaten to leave	Stay, pass on costs, no resistance
Difficult to pass costs to passengers	Move to lower cost alternative	Stay, resist imposition of costs

Table 1.1 Airlines Strategic Response to Noise Management Strategies
(Source: Gillen et al, 1990)

1.3 Study Objectives

Major bodies and the way their transactions affect airport management is shown in model form by figure 1.2. Each of the contributors play an important part in having an effect on the others. The aim of this research is to model the behaviour of airports, airlines and their passengers within the framework of the six major airports in England. Initially with the current air transport movements categorised by aircraft types, a landing charge based on the social cost of aircraft noise is developed. Based on the relationship of the above model, the social cost of noise if passed onto airlines who, if they subsequently pass on the cost to passengers, will then affect the chain of supply and demand as depicted by the arrows in the model.

An airport choice model distinguished by three market types: long-haul international scheduled, short-haul international scheduled and charter international is then developed based on existing patronage from different regions of UK. This study attempts to demonstrate how the new pattern of airport choice by market types and by different passenger groups may result as the new noise related landing charge is implemented. This study attempts to model the airport choice behaviour of international passengers only and does not model the case of the domestic passengers.

Bearing this concept in perspective the two major objectives of the study are:

a To develop noise related landing charges for six of the major airports in England

b Evaluate the implication of the noise charges on passengers' choice of airports

To pursue these two objectives, a number of associated areas of study are identified. First the units used for the measurement of aircraft noise are reviewed, focusing on European and US airports and their differences in adoption. The effect of aircraft noise on human beings is also addressed with particular attention to recent findings on aircraft noise and sleep disturbance. The current practices whether regulatory or operational used at airports, for containing the impact of noise are examined.

Whether aircraft noise affects the prices of residential properties is an important area of research, surrounded by controversy for some time. This issue is discussed in this research since the noise landing charge to be developed is based on the "Polluter Pays Principle". Previous landing charges based on the polluter pays principle are also reviewed in this study.

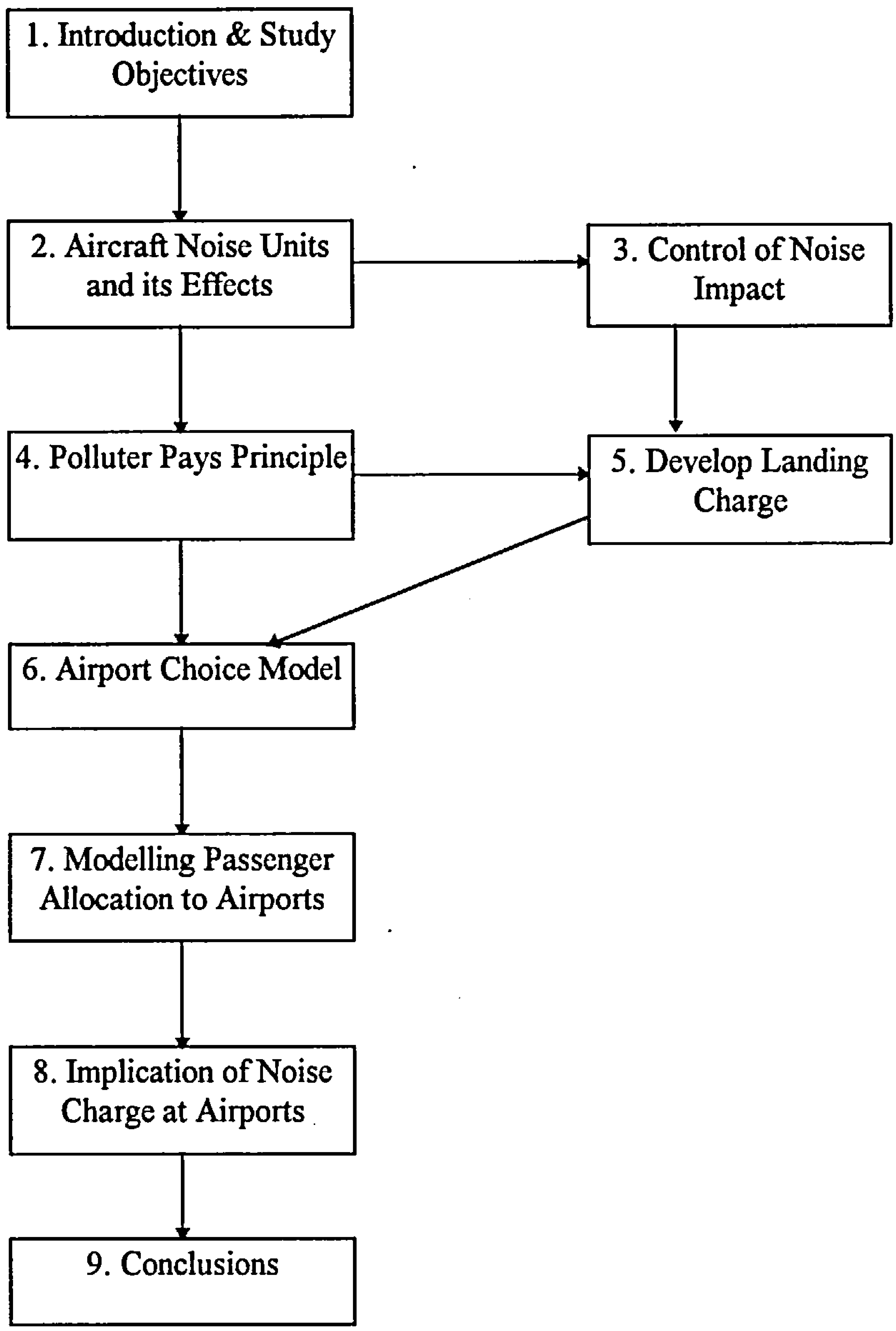
To determine the effect of the noise charge on passengers, an airport choice model is developed for the six airports.

1.4 Thesis Structure

A diagrammatic representation in which the chapters are structured is shown by figure 1.3. Chapter one introduces the subject with the background and sets the objectives of the study. The scope of the noise problem in its present form, the alternative strategy to manage it and the likelihood of its implications are presented in this chapter. In chapter two, units used for measuring aircraft noise particularly in Europe and USA are reviewed together with recent findings of aircraft noise effects on human factors. The measures which are used collectively by regulatory bodies, and generally independently adopted by airports to contain noise exposure are presented in chapter three.

An alternative method used to assess pollution is discussed in chapter four, which leads to the development of the noise related landing charge in chapter five. An airport choice model is derived in chapter seven, with the necessary background assumptions related to the noise charge discussed in chapter six. Chapter eight then assess the implications of the landing charge on passengers' choice of airports. In chapter nine conclusions and recommendations are made regarding this research.

Figure 1.3 Flow Diagram of the Thesis Structure



1.5 Summary

Aircraft noise at airports is a growing concern amongst leading members of the air transport industry. Since the early 60's the subject has been receiving attention and it has come to realisation that economic mechanisms are now required to control noise impact, while improvement for technological solutions are given more elapsed time. There is evidence that the 'Polluter Pays Principle" on which the landing charge is developed in this research is gaining wider acceptance throughout industries.

Passengers will be affected in different ways depending on their characteristics, and it is intuitive that an airport choice model is required to assess the implication. In modelling the entire aspect of the subject the study is structured into nine chapters.

REVIEW OF AIRCRAFT NOISE MEASUREMENT AND ITS EFFECT

2.1 Introduction

There are two parts to this chapter, of which the first section examines the various units which are used to measure aircraft noise and community annoyance and the second section looks at the effect of aircraft noise on human beings. The current situation for the unification of aircraft noise measurement units by international organisations such as ICAO and the level of progression to achieve this is reviewed. The landing charge developed in this study is based on the Noise Number Index (NNI), which has been used at UK airports since its development in 1963 (McKennell, 1963). However in recent years this unit has been replaced by the Equivalent Continuous Sound Level (L_{eq}). Thus this topic of L_{eq} replacing NNI deserves special attention and the main findings for which the NNI has been replaced by L_{eq} is discussed here. A Summary of the most important units used for the measurement of aircraft noise is covered in the first section. This chapter does not attempt to discuss in terms of reliability and credibility the annoyance factors with respect to the derivation and validity of the noise indices. How well each noise index correlate to annoyance, is a subject which deserves full attention on its own merit, and it is beyond the scope of this study. For a fuller understanding on the physics of noise such as its energy contents, speed, propagation, absorption, in summary the acoustics of noise the reader is referred to Ford (1987).

The second part of this chapter is concerned with the effect of aircraft noise on human beings. All the effects are categorised under three broad terms; annoyance, health effects and sleep disturbance. How annoyance leads to other immediate, attitudinal and behavioural factors is also mentioned. Much of the discussion is based on the latest research by UK Department of Transport and Civil Aviation Authority on sleep disturbance due to aircraft noise, as it is one of the latest pieces of research carried out on this subject.

Noise is defined as 'unwanted" sound (Committee on the Problem of Noise 1963). All noise is sound, there being an element of subjectivity in its measurement involving an individual's perception and attitudes. At one end it is the measurement of energy transference, whilst at the other it is the understanding of human perception and attitude formation. The interface between these two disparate subjects has found modest success (Starkie and Johnson, 1975) where laboratory conditions are used to reflect real life situations for the measurement of annoyance due to noise. The relationship between noise and the way people react, involves large numbers of intervening social and psychological factors which are extremely complex. The complexity is such that it is unlikely it will ever be completely understood (Ollerhead, 1989). The vast amount of research involved in understanding the nature of the problem is the very reason as to why there are so many noise indices available for use in many countries and the cause for the replacement of one unit with another.

A number of scales exist to express noise levels. There is no generally accepted noise scale, and only a few of the available scales have gained wide acceptance (Ashford and Wright, 1979). There are no international standards employed for the measurement of airport and aircraft community noise although there are several standards technical committees (SAE A-21 "Aircraft Noise Measurement Committee and ANCAT-Abatement of Nuisance caused by Air Transport, Technical Committee of ECAC), who refine drafts of data provision and noise footprint production. An International Standards Organisation (ISO 1979 equivalent to British Standard BS 5727) method exists for the measurement of aircraft noise as heard on the ground. However, for the measurement of aircraft noise ICAO Annex 16 (1971 and subsequent revised editions) and Part 36 of FAA Regulations have a procedure which refers to the International Aircraft Noise Certification.

2.2 Levels, Scales and Ratings

Noise levels, scales and ratings are all concerned with the human assessment of noise. A noise level refers to the instantaneous value of sound, noise scales combine levels with variation in time or frequency of occurrence and ratings take into account the specific time of day and possibly by season.

Loudness is the subjective magnitude of sound (Starkie and Johnson, 1975) and it is specified in decibels dB. This is a logarithmic scale well suited to human hearing which is logarithmic rather than linear in its behaviour. Loudness is normally considered to double with an increase in sound intensity of 10 dB. Human hearing is not equally sensitive to all frequencies. The variation with frequency is a function of level and the variation being less for very loud sounds than near the hearing threshold. The audible spectrum of sound is from 20 Hz to 20 KHz and the maximum sensitivity to sound is perceived around the middle of this range. Over the years a number of noise rating methods have been proposed, with the accepted scales being developed based on the human reaction to loudness. The "A" weighting amongst others has been identified to be the most appropriate.

The "A" weighting is now used for all levels of noise and its measurement is in units of dB(A). Since the "A" weighting was introduced there have been several surveys correlating subjective reaction with objective measurements, but no weighting has proved to be significantly better than the "A" weighting, which is why it has now been almost universally adopted for the measurement of transportation noise.

2.3 Aircraft Noise

Aircraft noise has a wide-ranging variable spectral characteristic and a transient, or rising then falling, intensity-time relationship (Smith, 1989). For this reason special assessment scales (Kryter, 1968; Young, 1969; Berglund and Lindvall, 1975) have been developed, which are annoyance based rather than loudness and which takes into account special spectral characteristics and the persistence of the sound.

Intensity of sound alone however is not a suitable measure. A factor that strongly affects the reactions of individuals and groups is time. Time as a variable, influences the subjective evaluation of noise in terms of; duration, repetition and the time of day at which it occurs. Aircraft noise falls under two categories, namely the single event measures and the cumulative event measures. There are a large number of noise indices available for both single and cumulative measures. Effective Perceived Noise Level (EPNL) and Sound Exposure Level (SEL) are thought to be the two principal measures of single event noise (Ashford, Stanton and Moore, 1984). The other important single event measure discussed in this study is Equivalent Continuous Sound Level (L_{eq}). Although L_{eq} is a single event noise descriptor (Jonckheere, 1989), it is normally used as a cumulative measure by the integration process over a defined period of time.

The units which fall under cumulative event measures discussed in this study are Noise Exposure Forecast NEF, Day-Night Equivalent Sound Level DNL or L_{DN}, Noise Number Index NNI, Isopsophic Index I and Equivalent Continuous Perceived Noise Level ECPNL. The single event measures are described first followed by the units which are under the category of cumulative measures.

2.3.1 Perceived Noise Level (PNL)

The perceived noise and effective perceived noise (PNdB and EPNdB) scales are uniquely related to aircraft annoyance (Smith, 1989). PNdB and EPNdB are used for aircraft noise certification and ICAO Annex 16 recommends contracting states for the use of EPNdB. However due to the complexity involved in calculating PNL, there is little application outside aircraft certification. The difference between PNL and EPNL is that EPNL modifies the PNL such that duration and maximum pure tone at each increment of time is taken into account. EPNL thus takes into account measures of sound level, frequency distribution and duration.

Originally annoyance response curves quantified by audiometric tests, reflected the nature of aircraft noise which were developed for the basis of PNL. Unfortunately the test sample used for this experiment did not reflect the cross section of the population.

The subsequent reevaluation led to the development of the contours of perceived noisiness shown in figure 2.1.

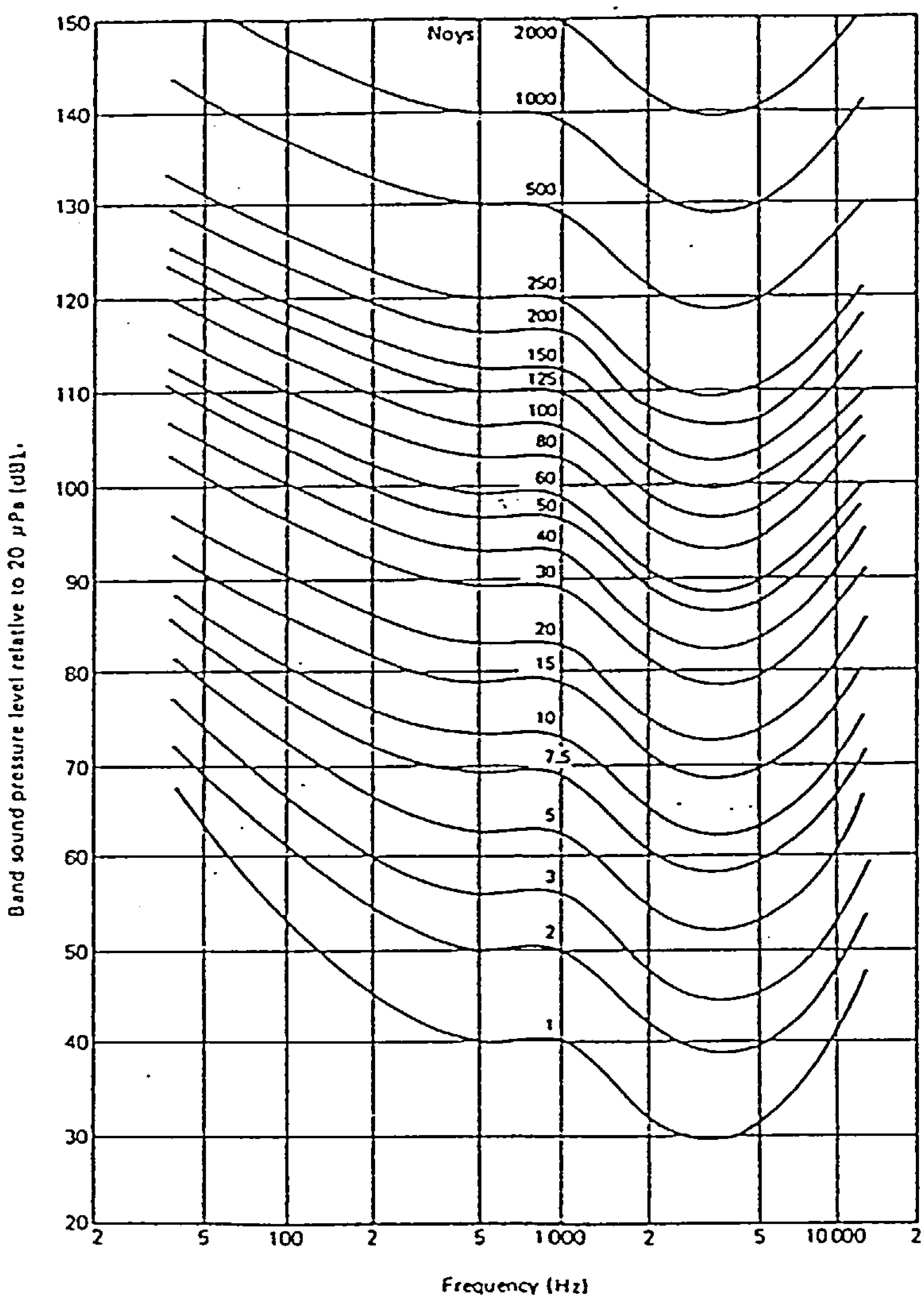


Fig 2.1 Contours of Perceived Noisiness

(Source: Smith, 1989)

This shows the response of the average observed test audience expressed in terms of level and frequency. PNL is based on this equal noisiness contours shown by the above figure. Their development was concerned with the high pitched whine associated with jet engine noise. During fly-over time intervals of 0.5s the noise level is measured and the full 1/3 octave band spectrum is determined. Each frequency band is converted to a noy value using the data in figure 2.1 for each time interval, noy being an unit of noisiness. According to the formula:

$$N = N_{max} + 0.15[\sum_{i=1}^{n} N_i - N_{max}]$$

the set of noy values is summed up. Where N_i is the noy value in band i and N_{max} is the maximum noy value of any band. The total noy value N, is changed back to PNL through the relationship:

$$L_{PN} = 40 + 33.3\log_{10} N(PNdB)$$

2.3.2 Effective Perceived Noise Level (EPNL)

The calculation of EPNdB is performed by integrating the energy over the time period during which the tone-corrected perceived noise level is within 10 PNdB of the maximum value and normalising with respect to a reference time of 10s (British Standards Institution ISO 3891-1978). The variation of PNLT for a typical fly-over where the integration period is between t_1 to t_2 is shown by figure 2.2. The EPNL is defined as:

$$L_{EPN} = 10\log_{10}[\frac{1}{10}\int_{t_1}^{t_2} 10^{L_{PNT}/10} dt]PNdB$$

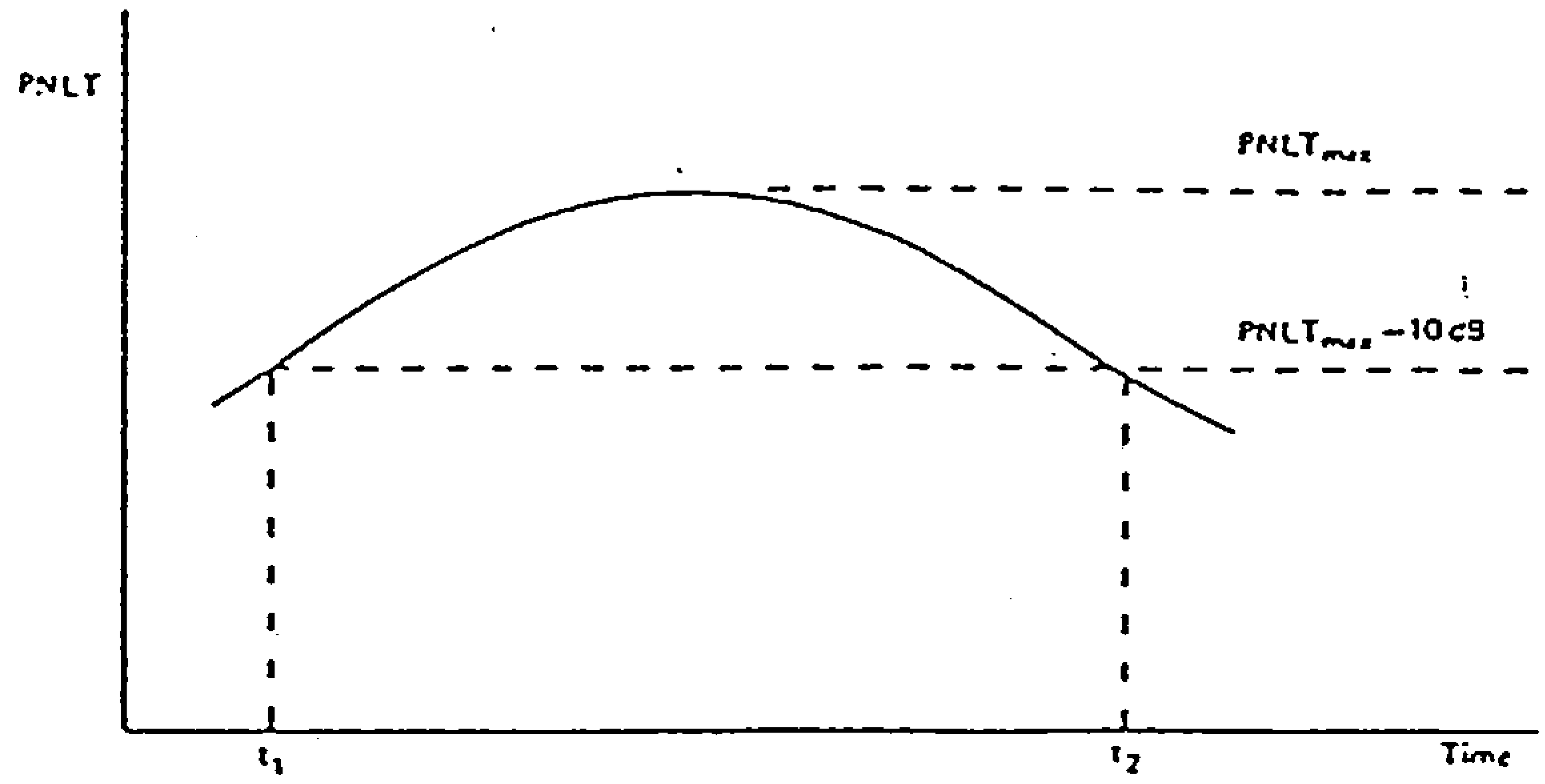


Fig 2.2 Typical PNLT history
(Source: Ford, 1987)

where L_{PNT} is tone corrected perceived noise level. In practical terms the integration is carried out as a summation, and if the values of PNLT are available at 0.5s intervals, the above equation becomes:

$$L_{EPN} = 10\log_{10}[\frac{0.5}{10}\sum_{i=1}^{n}10^{L_{PNTT}/10}$$

$$= 10\log_{10}[\sum_{i=1}^{n}10^{L_{PNLT}/10}] - 13PNdB$$

10s is thought to be an appropriate time for a typical fly past, thus 10s is taken to normalise those aircraft that make a lot of noise.

2.3.3 Equivalent Continuous Sound Level L_{eq}

In the late 1970's, a major study on the effects of aircraft noise on sleep disturbance was undertaken in the UK ("Aircraft Noise and Sleep Disturbance" CAA-DORA Final Report

8008). The objective was to establish the nature and extent of sleep disturbance with all cases of noise near major UK airports and assess the relationship between aircraft noise and sleep disturbance. In this study it was found that (Noise Advisory Council, 1978) continuous sound level (L_{eq}) gave quite a satisfactory correlation between aircraft noise exposure and sleep disturbance. The L_{eq} contains the same quantity of sound energy over a defined time period as the actual time varying sound level. The level is "A" weighted prior to the averaging process, i.e.:

$$L_{eq} = 10\log_{10}[\frac{1}{10}\int_{0}^{T} 10^{L_A/10} dt] db(A)$$

where T is the time period and L_A is the "A" weighted noise level. L_{eq} is normally defined over a relatively long time e.g. 1, 8, 12 or 24 hours. However as a measure of noise nuisance it is frequently criticised because it de-emphasises occasional noisy events (Ford, 1987). The energy continued in a short burst of high level noise is distributed into the quieter parts by the time averaging process.

2.3.4 Single Event Noise Exposure Level, SENEL, SEL or L_{AX}

Sound Exposure Level or L_{AX} is defined as the continuous sound level which, when maintained for 1s, contains the same quantity of sound energy as the actual time varying level of one noise event (noise Advisory Council, 1978). Like L_{eq} this level is "A" weighted prior to integration. In practice the integration is limited to the time during which the actual noise level is within 10 dB(A) of the maximum, i.e.:

$$L_{AX} = 10\log_{10}[\int_{t_1}^{t_2} 10^{L_A/10} dt] dB(A)$$

where t_1 and t_2 denote the beginning and end respectively, of the single event. SEL is used for the calculation of L_{eq} and day-night equivalent levels (L_{DN}). For a given time period L_{AX} defines the energy contribution of the single event. The value of L_{eq} over the period T from a number of single events is given by the formula:

$$L_{eq} = 10\log 10[\frac{1}{T}\sum_{i=1}^{n} 10^{L_{AXi}/10}] dB(A)$$

2.3.5 Noise Exposure Forecast NEF

The noise exposure forecast was developed in the USA for assessing the effect of noise from civil aircraft (Bolt, Beranek and Newman, 1964 and 1965). The NEF used the EPNdB rather than the simple dBA and the number of events. For a particular type of aircraft i on flight path j producing $EPNL_{ij}$, the contribution to the NEF is:

$$NEF_{ij} = L_{EPN_{ij}} + 10\log_{10}[n_{Dij} + 16.67 n_{Nij}] - 88$$

where n_{Dij} is the number of daytime flights (0700-2200 hours) and n_{Dij} is the number of night time flights (2200-0700 hours). The total NEF is then given by:

$$NEF = 10\log_{10}[\sum_{i}\sum_{j}10^{NEF_{ij}/10}]PNdB$$

The constant 16.67 is applied to night time operations meaning that for the same average number of operations per hour, the NEF correction will be 10 dB higher for night time operations. The constant 88 is chosen to ensure that a zero or a very small value of NEF corresponds to no noise impact, and that NEF values confine to a range of other similar ratings. However despite being used for a long time in the United States, NEF has now been replaced by the day-night sound level (L_{DN}).

2.3.6 Day-Night Equivalent Sound Level, (DNL or L_{DN})

This rating originated in the USA (Office of Noise Abatement and Control, 1974) and is based on the equivalent continuous sound level (L_{eq}). The L_{DN} fully recognises the importance of the duration element of noise, thus it uses the integrated dB(A) of the sound exposure level (SEL) rather the basic instantaneous or peak dB(A) level. The energy is averaged over 24 hours but the noise level during the night-time period defined from 2200 to 0700 hours, is penalised by the addition of 10 dBA. The addition of 10 dBA is to reflect the increased annoyance when urban background noise levels are low, particularly during late evenings and overnight (Rice, 1982; Borsky, 1976; Ollerhead, 1977; Taylor, 1980). L_{DN} is given by the formula:

$$L_{DN} = 10\log_{10}[\frac{1}{24}\int_{7}^{22}10^{L_A/10}dt + \int_{22}^{1}10^{(L_A+10)/10}dt]dB(A)$$

Despite numerous attempts in trying to understand the relationship between night time noise and day time noise annoyance, the concept of penalising night time noise by 10 dB(A) is probably based more on common sense rather than experimental evidence (Ford, 1987). L_{DN} can be criticised for not making allowance for tonal or impulsive content of noise, however it has found widespread acceptance in the USA for community noise assessment.

2.3.7 Noise Number Index (NNI)

The Noise Number Index is a long term average measure of noise exposure. Initially NNI was developed in the UK (Wilson Committee, 1963) based on a social survey of people living in the vicinity of London Heathrow Airport (McKennell, 1963). It demonstrated a relationship between average (i.e. community) annoyance and aircraft noise exposure expressed as NNI. The NNI combines the maximum perceived noise level of each aircraft with the number of movements according to the formula:

$$NNI = 10\log_{10}[\frac{1}{n}\sum_{i=1}^{n}10^{L_{PNmaxi}/10}] + 15\log_{10} n - 80PNdB$$

In the calculation of NNI, only aircraft that make noise level exceeding 80 PNdB or more are included, as it is taken that 80 PNdB corresponds to zero annoyance. The time period 0600 to 1800 hours GMT is used for the evaluation of NNI. In theory based on the 10 dB(A) penalising factor for night time operations, NNI can be calculated on a similar principle that is 80 PNdB reduced to 70 PNdB.

2.3.8 Isopsophic Index (I)

Originally Isopsophic index I began as two separate expressions, one for day and the other for night, but now both have formed into a single expression for the 24 hours with night time events weighted by 10 dB(A). The index was initiated in France (Alexandre, 1970) and is defined as :

$$I = 10\log_{10}[\sum_{i=1}^{n_D} 10^{L_{PN_{max\,i}}/10} + \sum_{j=1}^{n_N} 10^{(L_{PN_{max\,j}}+10)/10}] - 32PNdB$$

where n_D is the number of day-time events (0600-2200 hours) and n_N is the number of night-time events (2200-0600 hours).

2.3.9 Equivalent Continuous Perceived Noise Level (ECPNL)

This measure expresses total noise exposure in terms of the equivalent continuous perceived noise level and ICAO recommends international adoption of it (Ashford, Stanton and Moore, 1984) The total noise exposure level (TNEL) produced by a succession of aircraft is expressed by:

$$TNEL = 10\log\sum_{1}^{n} anti\log\frac{EPNL(n)}{10} + 10\log 10$$

where EPNL (n) = effective perceived noise level for the n^{th} event. For comparison purposes, the TNEL from a succession of aircraft is expressed in terms of the equivalent continuous perceived noise level (ECPNL), which is derived from:

$$ECPNL = TNEL - 10\log\frac{T}{t_o}$$

where T = total period of time under consideration in seconds and $t_o = 1$ second

It can be seen that various noise descriptors are available for the quantification of aircraft noise emission and the impact it has on local communities in terms of annoyance. Each noise index has its own requirements for measurement and computation. Some of them have certain similarities, others differ fundamentally.

Table 2.1 (Large and Michael, 1981) summarises the various units commonly used for the measurement of aircraft noise in various countries. The exception in this table is that L_{eq} has now replaced NNI in the United Kingdom and Day Night Level (L_{DN}) has replaced NEF in the United States. NNI and NEF have a number of similarities, both use the PNdB as their descriptor. NEF uses a value of 88 compared to NNI using 80 to correspond to zero annoyance. Thus the principles of both these noise measures are the same.

As far as the noise landing charge is concerned, the valuation of social cost of aircraft noise around airports carried out so far have relied on the NEF and NNI units. Table 4.1 in chapter four summarises the results obtained by various research using NEF and NNI units. It shows the impact of unit increase in noise levels on the prices of houses near airports in various cities.

The most recent work by Levesque (1994), models the effects of airport noise on residential housing markets using the NEF. His study attempts further to decompose the cumulative measure and tries to emphasises the importance of specific variables such as, sound pressure levels and frequencies of overflights as factors influencing residential property values. Collins and Evans (1994) also examine aircraft noise and residential property values using the NNI system for Manchester International Airport. Although rather out of date, this demonstrates the importance of the two units being used in the same purposes. For many airports noise contour maps at the time in which this study was carried out, had not yet been fully converted to the L_{eq} system. For this reason the noise charge developed in this study uses the NNI system as it is the only choice available.

Country Origin	Title (and usual symbol)	Definitive Expression	Approx. Correction from L_{eq12h}	Notes
United Kingdom	Noise and Number Index - NNI	$\overline{L_{PNmax}} + 15 \log_{10} N - 80$	−22 at 100/day	1
Federal German Republic	Storindex Q, L_{eq}	$13.3 \log_{10} \sum_i \frac{t_i}{T} \times 10^{\left(\frac{L(A)_i}{13.3}\right)}$	−35 (on departure)	2
France	Indice Psophique I	$10 \log_{10} \left[\sum_{i=1}^{n} 10^{(N_i/10)} + \sum_{j=1}^{p} 10^{(N_j + 10)/10} \right] - 32$	+2 at 100/day and $p = 0$	3
Netherlands	Noise Exposure (Kosten Unit) B	$\left[20 \log_{10} \sum_i n_i \times 10^{\left(\frac{L(A)_i}{15}\right)} \right] - 157$	−	4
ISO	Aircraft Exposure Level L_E	$\left[10 \log_{10} \sum_i 10^{(L_{EPN}/10)} \right] + 10$	≈ + 20	
United States	Noise Exposure (Forecast) - NEF	$L_{EPN} + 10 \log_{10} (N_D + 16.67 N_N) - 88$	≈ − 50 at 100/day (no night events)	5
United States	Day Night Level L_{dn}	$\begin{bmatrix} SEL(A) \\ \text{or} \\ L_{AX} \end{bmatrix} + 10 \log_{10} (N_D + 10 N_N) - 39.4$	−3 for no night events	5
EEC European Economic Community	Equivalent Level $L_{eq}(A)$	$\begin{bmatrix} SEL(A) \\ \text{or} \\ L_{AX} \end{bmatrix} + 10 \log_{10}(N) - \begin{bmatrix} 36.4 \\ \text{or} \\ 39.4 \end{bmatrix}$	Datum (12 hour)	6

Notes:

1 Evaluated over mid June to mid October, airport movements during 0600 - 1800 Greenwich Mean Time only

2 g_i weighting for night (evaluated separately) equivalent to +5 dB. Evaluated from 6 a.m. to 10 p.m. and 10 p.m. to 6 a.m. respectively for six busiest air traffic months. t_i is duration(s) at 10 dB(A) below maximum, T is total time period per evaluation (= 15552 x 10^7)

3 n is the number of daytime flights with individual L_{PNmax} = N_i, p and N_j similarly refer to nighttime operations.

4 n_i is time of day weighting (23-6 hours = 10, 6-7 hours = 8, 7-8 hours = 4, 8-18 hours = 1, 18-19 hours = 2, 19-20 hours = 3, 20-21 hours = 4, 21-22 hours = 6, 22-23 hours = 8)

5 N_D = number of daytime flights, 0700-2300 hours; N_N = number of nighttime flights, 2300-0700 hours. Formula is for an aircraft type with given average noise descriptor values. Summation for all types and tracks by energy method.

6 Alternative constants relate to L_{eq12h} and L_{eq24h} respectively, summation across types and events as in 5

Table 2.1 (Source: Large and Michael, 1981)

Although a large number of aircraft noise measurement units are used in various countries, there have been individual and collective attempts for the unification of adopting single measures which are satisfactory. This was recognised as a desirable objective as early as the 1970's (Ollerhead, 1977). There are a number of similar methods available for the prediction of noise contours and ICAO states for example are trying to harmonise the methodology to bring the common major elements together (ICAO Circular, 205-AN/1/25, 1988). Due to the complexity of calculating EPNL, there have been attempts (Ibanez, Belenguer and Diaz, 1985) to determine relationships between SEL and EPNL, to reduce confusion in terms of common use of aircraft noise indices.

The L_{DN}, NNI and NEF are very similar in basic form, and there is evidence indicating that community response to noise impact can be correlated to any of these measures (Ashford, Stanton and Moore, 1984).

Another similarity of noise measures such as NEF, L_{DN}, I and CENEL is that all penalise night time noise by 10 dB. Although evidence to suggest that night time noise should be weighted by 10 dB, is subject to criticism (Ollerhead, 1978) it does however demonstrate that there are similarities between the various units for the assessment of annoyance of aircraft noise. A night time landing charge will also be developed in this study based on this 10 dB penalising factor using the NNI system.

2.4 Replacement of NNI with L_{eq} at UK

The NNI has been used in the United Kingdom since 1963, originally derived from a study into the nature and effect of noise on people living near Heathrow Airport. In recent years the L_{eq} (16 hour) based on dB(A) has replaced the NNI. This was done through consultation with the Aircraft Noise Monitoring Advisory Committee (ANMAC) who agreed that a 16 hour L_{eq} should be calibrated against NNI annoyance.

"There is no absolute measure of disturbance from aircraft noise, nor can there be, given the variation in individual reactions. Initially NNI was generally accepted as a reasonable indicator. There was a very good correlation between NNI and the levels of community annoyance as measured by social surveys but over the years it has become increasingly subject to criticism", (Department of Transport, Minister of Aviation, 1990).

There were in total sixteen criticisms against the continuation of use of NNI. Some criticisms are stronger and more important than others. Although the decision was taken to replace NNI with L_{eq}, there were substantial critics who suggested that the change of unit should be done in parallel with continuance of NNI between two to five years. Some of the most important criticisms for which the NNI was replaced by L_{eq}, extracted from Department of Transport, 1990 "Day time Aircraft Noise Index - change from the NNI to L_{eq}" are mentioned below;

(i) is out of date (aircraft have changed, people's views of noise may have changed etc.);

(ii) does not conform with indices used elsewhere in the world (many of which are based on L_{eq});

(iii) is of the wrong basic form (i.e. a better formula could be obtained);

(iv) is unsuited for extrapolation (i.e. for forward projections using the noise levels and numbers of more modern aircraft);

(v) uses "average mode" operations (rather than "worst mode" situations in the use of particular runways);

(vi) its derivation involved the use of Guttman Annoyance Scale (GAS) which has been challenged as unsuitable;

(vii) makes no allowance for night time noise (as NNI is measured between 0700 and 1900 local time).

Although the use of L_{eq} has been taking place since 1989, accurate data on the size of population affected by aircraft noise around various airports and the noise contour maps in L_{eq} were not available towards the end of 1991. For this reason the landing charge developed in this study, still uses the NNI unit. Collins and Evans (1994) research, on the effect of aircraft noise on residential property values around Manchester International Airport uses the NNI. This provides confirmation to the approach taken in this study. However, in principle the L_{eq} can be used in a similar way for the assessment of the noise related landing charge.

2.5 Introduction To Aircraft Noise Effects

Aircraft noise is the major nuisance to residential communities around airports (Ollerhead, 1973). Generally transport noise and in particular aircraft noise, the effects on people are various and interrelated. Research carried out from the time aircraft noise recognised to be a nuisance reveals that the effects of noise are numerous, some of which include:

Communication interference
Activity or task interference
Sleep annoyance
Stress and related physiological responses
Hearing problems

The above list has been compiled from Ollerhead, 1977 and Hede, 1982 with other researchers in this field draw similar conclusions (OECD "Fighting Noise", 1986). The interrelationships between noise and the way people react are complex. For example, speech interference can cause annoyance and tiredness and reciprocally tiredness may exarcebate annoyance. Relationships also exist between the general state of health and the various effects of noise, particularly if it is over the long term and this is not confined to aircraft noise alone but also other sources of noise such as at work (Ollerhead, 1977). Stress may develop due to the presence of noise, which may induce physiological changes in the body and a general decline in health and well being.

The effect of aircraft noise discussed in this section is categorised by three topics: Annoyance, Health Effects and Sleep Disturbance. The chapter summarises the latest findings with respect to the three topics, it is not within the limits of this study to provide detailed explanations of the acoustical research involved in finding say the relationships between speech interference and annoyance in laboratory conditions. For detailed studies on the acoustical aspect of the topic refer to Fields and Hall (1987) also Kryter (1970).

2.6 Annoyance

The most widely accepted formal definition of annoyance is "a feeling of displeasure associated with any agent or condition believed to adversely affect an individual or a group" (Lindvall and Radford, 1973). In trying to understand annoyance, two concepts have been realised, cognitive evaluation of sound and the emotional reactions caused by the sounds (Weinstein, 1976). The first concept refers to judging whether the noise level complies with some abstract standard of environmental quality and the second concept measures the impact of the sound on the person's emotions (Fields and Hall, 1987).

Research is still being carried out to determine the effect of aircraft noise, but by far it has been identified to cause annoyance (Ollerhead, 1973). Figure 2.3 presents a simple diagram showing the community response to noise. To understand in detail the relationships between annoyance and noise exposure level refer to Field and Hall (1987) and Kryter (1970).

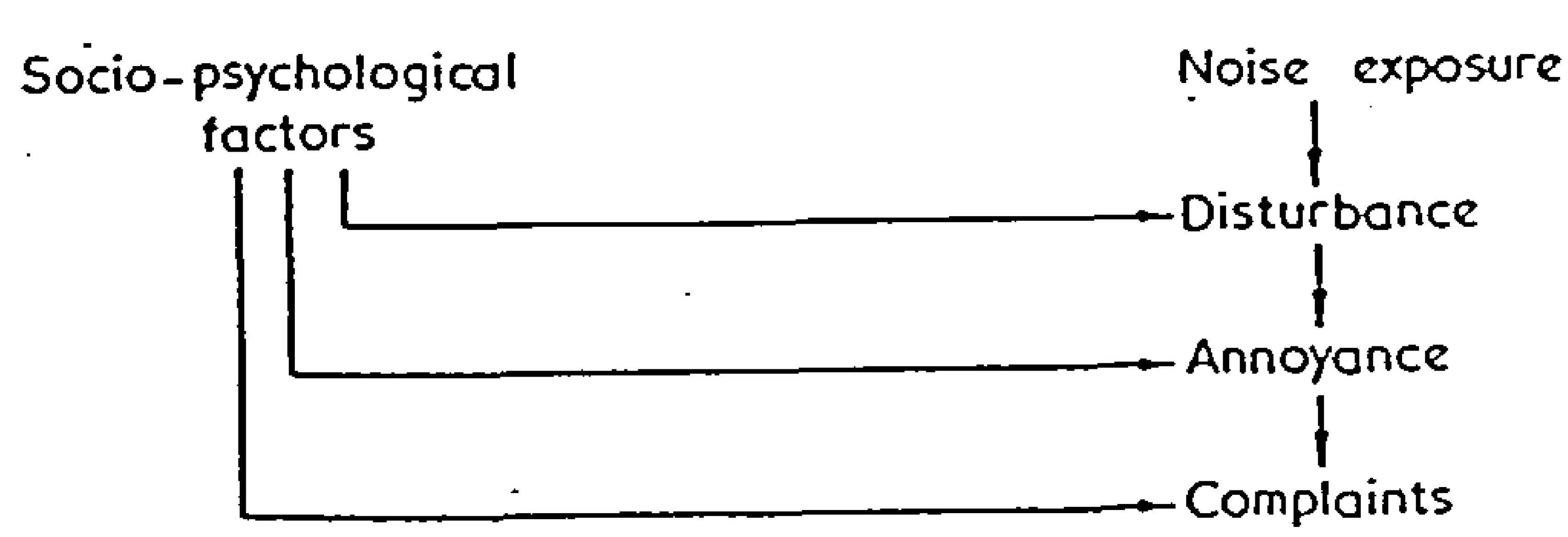


Fig 2.3 Community Response to Noise
(Source: Ollerhead, 1973)

Figure 2.4 shows a general model of the most important relationships between noise, and the social context in which the annoyance effect arises. The main concern of this section is annoyance, thus the arrows which relate annoyance to other factors i.e., immediate effects, personal and attitudinal factors, behavioural modifications will be reviewed here.

The main subjects which fall under the heading of immediate effects from the list compiled earlier are (Ollerhead, 1977 and Hede, 1982); speech/communication, activity or task interference and hearing effects. Health effects and sleep disturbance will be discussed on their own merit.

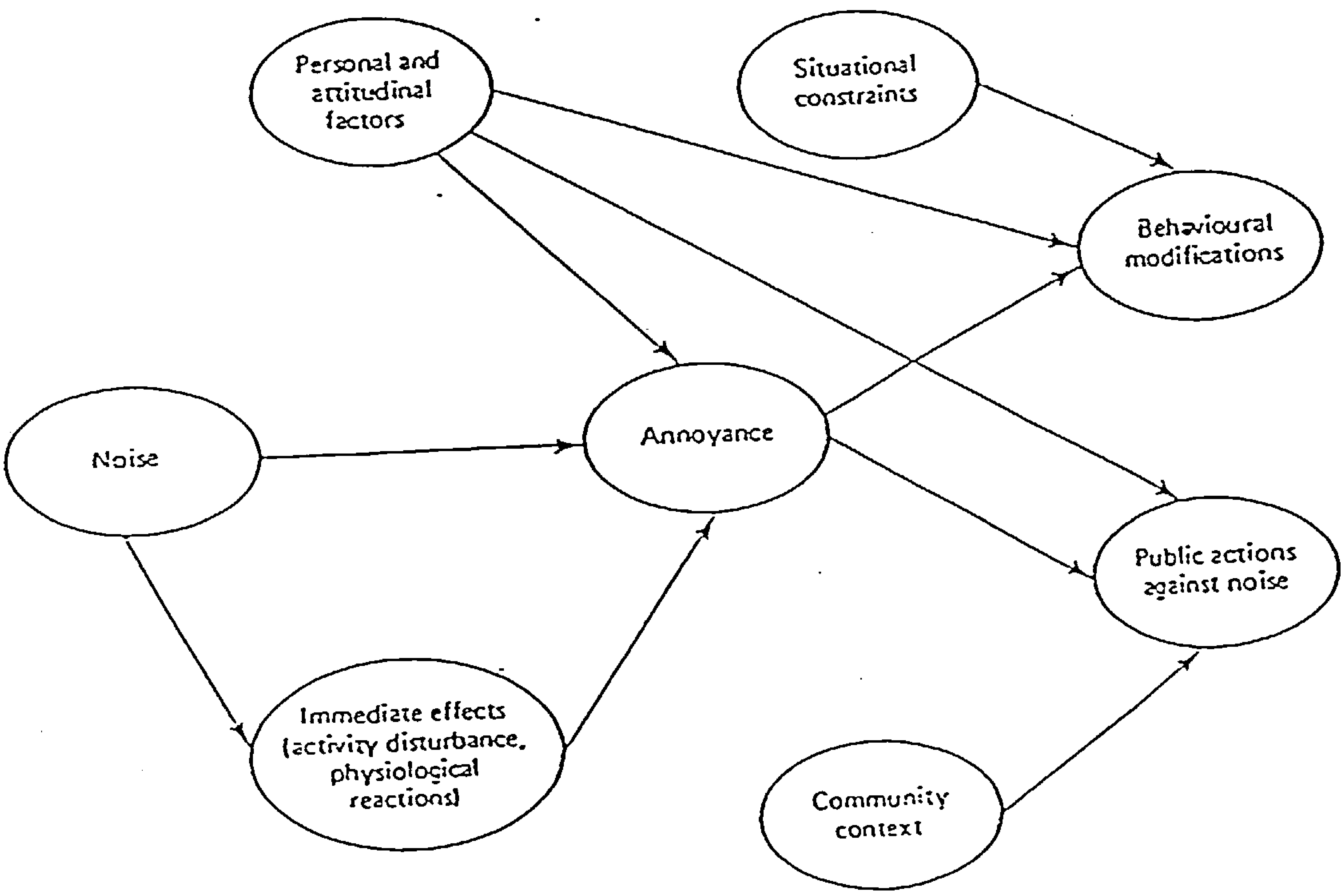


Fig 2.4 Relations Between Noise Effects and Community Settings
(Source: Fields and Hall, 1987)

The immediate effects of noise include physiological effects, startle responses and activity disturbance to both communication and concentration (Fields and Hall, 1987 and Ollerhead, 1977). Earlier research by Ollerhead (1973) and later research by Hede (1982) reveal that the direct impact of noise is to cause disturbance to every activity such as communication and concentration. OECD (1986) also found that noise takes effect via two independent physiological mechanisms, through the hearing and indirectly in the regulation of attention and behaviour.

In a more recent social survey carried out in a selection of airports in Australia (Hede, 1982) reveal similar findings to previous surveys carried out at Heathrow (HMSO, 1967) and Geneva, Switzerland airports (1972) that activity interference increases with increase in noise level. Four immediate effects are aural communication interference, sleep interruption, startle reactions and concentration interruptions. Figure 2.5 shows the relationships between activity interference and noise level from the social survey at Geneva, airport. This same pattern has been replicated for Amsterdam airport (Kosten et al, 1967) and Yakota airbase (Kodama, 1971), Osaka airport (NASA TM -75439, 1980) and Chitose airport in Japan.

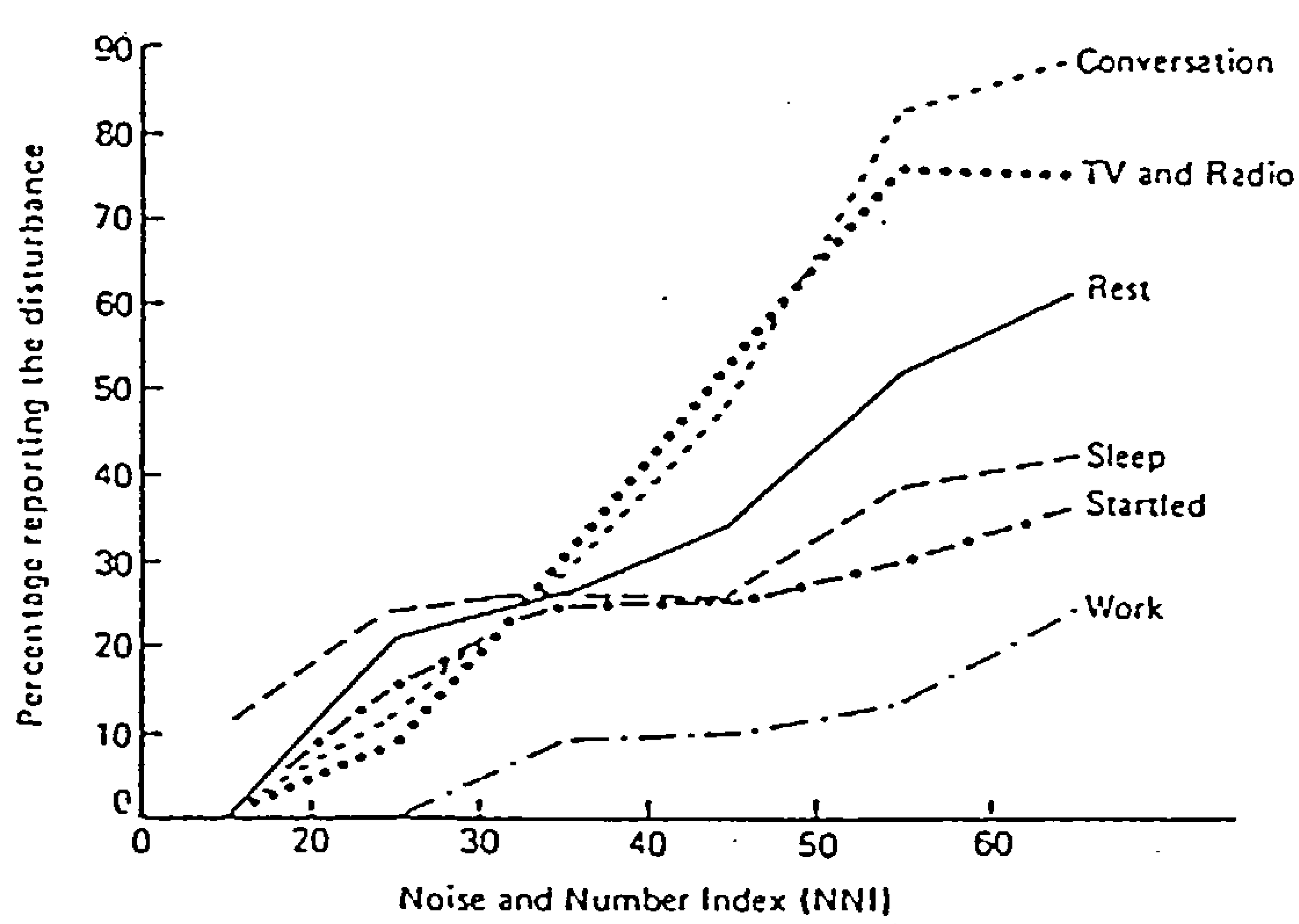


Fig 2.5 Relation Between Activity Interference and Noise Level.
(Source: Mueller, 1973)

It has been found that annoyance also depends on attitudinal and personal factors. In the case of aircraft noise, it has been established that a person's reaction to it is highly influenced by his fear of aircraft crashes (Ollerhead, 1973 and HMSO, 1971). A person with highly negative attitude is likely to be highly affected by a small amount of noise, whereas someone with positive attitudes will be almost unaffected even by high exposure (Hede, 1982). The other important variables are his attitude towards airports and air transportation in general. Whether he receives any direct personal benefit, and upon his opinions about official concern, that is whether the responsible authorities are worried about the noise and whether or not they are trying to do anything about it (Fields and Hall, 1987; Ollerhead, 1973; Ashford and Wright, 1979).

To illustrate the seriousness of the aircraft noise problem, it is necessary to conclude the annoyance factor by relating it to behavioural modifications. Behavioural adjustments take form either publicly or privately. Two extreme cases of private behavioural adjustments are closing windows for improving communications and wanting to move locations entirely. Although investigations have found that noise level is related to wanting to move (McKennel, 1969), no study has found that moving plans are related to noise level (Fields and Hall, 1987). At a public level demonstrations, complaints, public meetings, circulation of petitions are some of the methods used to show disapproval for noise standards, as has been the case at the London airports when the new proposals were introduced for night time flights (Department of Transport UK Consultation Paper, 1993).

2.7 Health Effects

The World Health Organisation definition of health which has gained wide acceptance refers to health as being more than the absence of disease; it is seen to encompass total physical and psychological well being. In this context, annoyance due to noise discussed earlier is considered as a health effect. However in noise literature the term "health effect" is used more broadly than the WHO definition implies, it refers to any measurable effect of noise on a body that are potentially detrimental (Taylor and Wilkins, 1987).

Meecham and Smith (1977) made the strongest claim relating mental illness to aircraft noise near Los Angeles Airport, concluding that admissions to hospitals are 29% higher from areas exposed to high noise levels. The methodology used to arrive at this result is subject to question, since important variables that may have significance such as age and gender were not taken into account.

A number of other studies were carried out to determine any relationships between aircraft noise and mental illness (Wickrama, Herridge et al, 1969; Gattoni and Tarnopolsky, 1981; Tarnopolsky, Barter et al, 1978; Jenkins and Tarnopolsky, 1981). These findings provide no strong evidence that aircraft noise effects psychiatric morbidity.

2.8 Sleep Disturbance

The relationship between sleep disturbance and aircraft noise is an extremely complex one. To determine the relationship between aircraft noise and sleep disturbance, it is necessary to understand the characteristics of sleep such as; nature and structure of sleep; techniques for evaluating the quality of sleep; transitory disturbances to sleep due to isolated occurrences of noise; noise and consumption of medicaments to aid sleep amongst many others. Research work as early as the 1970's postulated relationships between aircraft noise and sleep disturbance (Collins, 1972; Ludlow, 1972; Lukas, 1970; Muzet, 1973; Thiessen 1973). The findings are many and diverse. Psycho-sociological inquires together with observation of sleeping subjects under both laboratory and field conditions are the main methods of evaluating sleep disturbance.

As more and more research is undertaken, more knowledge is revealed which contributes towards the understanding of the subject. There being no exception to the rule if recent findings are judged better, that they overrule previous conclusions.

The UK Department of Transport in collaboration with Civil Aviation Authority recently undertook detailed research concerning aircraft noise and sleep disturbance (Ollerhead et al, 1992) to aid policy making regarding night time flights at the London airports, since current night restrictions were based on studies of effects of noise on sleep some ten years ago. This research is one of the most recent on aircraft noise and sleep disturbance. The report was based on a field study in areas adjacent to Heathrow, Gatwick, Stansted and Manchester airports and leading experts on sleep disturbance were consulted before drawing conclusions regarding the findings of this report. The discussions here will be based on this report produced by Department of Transport on aircraft noise and sleep disturbance.

The findings of this research were individual sensitivity, certain level of aircraft noise, sex, time of night were factors affecting sleep disturbance. The report concluded that individual rates of sleep disturbance varied markedly: after statistically controlling for the effects of aircraft noise, gender and time of night, the 2-3% most sensitive individuals were disturbed over 60% more than the average.

The results showed that aircraft noise events (ANEs) are most unlikely to cause measurable increase in the overall rates of sleep disturbance experienced during normal sleep below outdoor event levels of 90 dBA SEL (80 dBA L_{max}). For outdoor event levels in the range 90-100 dBA SEL (80-95 dBA L_{max}) the chance of the average person being wakened is about 1 in 75. Individual deviation from the average are substantial. It is possible that for aircraft noise related disturbance, the variability is even greater, compared with the average the 2-3% most sensitive people could be over twice as likely to be disturbed. Whereas the 2-3% least sensitive people to noise are less than half as likely to be disturbed for the same level of noise.

It is found that overall men are more disturbed from sleep by about 15% more frequently than women and that this is true for all causes of disturbance, not specifically aircraft noise. Effects of age was found not to be statistically significant.

Time of night and time of sleep onset are significant factors. People appear to be more resistant to disturbance from any cause, after first falling asleep. If sleeping time is divided into cyclic periods and 90 minutes counted as one cycle, then it is found that after the first cycle, the overall disturbance rate increases steadily, from the equivalent of about two awakenings an hour at the beginning of the night to about three per hour at the end of the night.

The field work was carried out at various sites around the four airports, however there was no statistical significance between the average arousal rates over the night at the different study sites. The state of the window whether single or double glazed, open or shut were found to have no statistical significance with arousal rates.

Research in this subject is an important prerequisite for policy making especially regarding night time flights. There is ongoing research to understand further the nature of this subject for example the possibility that people are most sensitive to disturbance by noise when sleep lightens, and less vulnerable when sleep deepens.

2.9 Summary

This chapter has covered two main aspects of aircraft noise, that is the units of measurement and its effect on human factors. Brief explanation of levels, scales and ratings and how they refer to the human assessment of noise has been looked at. There are two distinct elements involved in developing units which measure aircraft noise. There is the technicality of measuring energy transference and associating that with human perception and attitude formation. This very reason has led to the development of the many units that are used to measure aircraft noise, and in the UK recently L_{eq} has replaced NNI as it was felt that NNI has outlived its usefulness. Although NNI system is no longer used in the UK, its relevance in this study has been discussed.

The most important units of aircraft noise are mentioned, whether they measure single or cumulative events. There is no common unit used for the measurement of aircraft noise however ICAO uses EPNdB for the Noise Certification purposes.

The effects of noise on human beings in terms of annoyance, health effects and sleep disturbance have been reviewed. No evidence has been found which relate health effects to noise within the definition of health effects adopted here. The factors that influence sleep disturbance have been identified and annoyance related to aircraft noise is an established concept.

At this stage aircraft noise annoyance which relates to values of property depreciation, has not been included in this chapter. The discussion on aircraft noise valuation using the hedonic approach is towards the end of chapter four. The concept on which the noise landing charge is developed in this study is based on the Polluter Pays Principle. Therefore noise valuation is carried out in the context that it is a form of pollution, which relates to annoyance.

CONTROL OF AIRPORT NOISE IMPACT

3.1 Introduction

The previous chapter reviewed the various important units that are used to measure aircraft noise around airports and its effect on people. This chapter is concerned with the policies that are used to control the impact of airport noise. Noise management strategies are employed at airports in Canada, USA, Europe, Japan and member countries of ICAO. Noise abatement, control and exposure strategies vary from country to country, within a country and from airport to airport (Levesque et al, 1990).

Meeting the problems of airport and aircraft noise requires co-operation from international organisations, aircraft manufacturers, airlines, airport authorities and local communities. Further noise abatement and policies adopted by individual airports depend on a number of factors such as, level of airport activity, types of aircraft services operating, ownership of airport, the existing and future population densities of the airport environment and the political climate of the community. All these factors make it difficult to apply similar strategies to all airports in order to contain noise. Having so many variables to be taken into consideration before arriving at meaningful action, has led to the proliferation of several different measures adopted for the noise problem (Spencer, 1990).

As an illustration of the diversity of the problem, approximately four hundred airports in the USA alone have adopted some form of action to reduce aircraft noise or to mitigate the effects of that noise. The noise control strategies fall into thirty seven categories, which describe the airports' procedures for noise abatement or mitigation. For a comprehensive list and detail see (Cline, 1986). It is not possible to describe all policies in this chapter, only the important ones are discussed that are widely used.

This chapter is divided into two main sections. The first section reviews the current state of aircraft noise exposures and the methods mainly in the form of regulatory policies used to alleviate it. The implications of such regulatory policies are also discussed. The second section looks at the policies adopted by airports to control noise impact. These measures fall into two broad categories: operational controls in the air and on the ground.

3.2 Control of Aircraft Noise Impact

Aircraft noise reduction at source is mainly carried out by using noise emission standards laid down by International Civil Aviation Organisation. Annex 16 of ICAO in most of the European countries and Federal Aviation Regulation (FAR) Part 36 in the United States. Retrofitting aircraft engines with sound absorbent materials (SAM), replacing engines often called "re-engining" and early retirement of aircraft in favour of noise certified ones constitute the major measures for noise abatement at source.

Retrofitting old aircraft with quieter engines has not been found to be the most cost effective solution (OECD "Noise Abatement Policies", 1980). The cost involved relative to the value of the aircraft are very large and this process most probably would extend the life of those aircraft, which would still remain noisy (OECD "The Costs of Noise Abatement", 1980).

Engine replacement is also an expensive process, in some cases the cost of replacement of engines can be as much as fifty per cent of the total value of the aircraft (Flight International, 1979). Early retirement is the third main method of controlling noise at source. The cost of replacement will depend on the age of the aircraft and its remaining lifetime. Thus cost calculations are likely to be sensitive to interpretations on the remaining lifetime of the aircraft.

The above three methods are resultant measures due to the standards by ICAO and FAR for aircraft noise abatement. This process of meeting certain noise standards by certain dates is known as Aircraft Noise Certification.

For noise certification three noise measurement points are defined: under the approach, under take-off paths and laterally to the side of the runway. Maximum noise levels are set at these reference measuring points, which are dependent on maximum certified take-off weight of aircraft. (The ICAO noise certification measurement points are diagramatically illustrated in chapter five, figure 5.2). These standards require aircraft types to conform with maximum permitted noise levels. Federal Aviation Regulations are slightly more stringent than those of ICAO. Although the noise levels are the same, there are minor differences in the locations of the measuring points (Ashford, Stanton and Moore, 1984). Aircraft types are categorised into three groups; Chapter 1, Chapter 2 and Chapter 3 for ICAO Annex 16 and Stage I, Stage II and Stage III for US FAR Part 36 which is analogous to the ICAO system.

On January 1, 2000, all airlines operating in the US must meet Stage III noise specifications outlined in FAR Part 36. In Europe and in the US, Stage II aircraft can no longer be added to an airline fleet, and ICAO nations have implemented a seven year phasing out program beginning in 1995. This requires that all airline fleets meet ICAO Annex 16 Chapter 3 noise standards by April 1, 2002, which is analogous to FAA's Stage III.

In the foreseeable future, the prospect of technological innovations to substantially reduce aircraft noise is limited (Smith, 1991). This view is shared by FAA (FAA, 1986) and others (Airports and the Environment, 1991). A survey of selected airports in Europe, the Middle East and North America by Airport Co-ordinating Council International (ACCI), showed that the noise impact would increase by 30% by the year 2000 unless all aircraft meet a minimum chapter 2 standard (Aviation Week & Space Technology, 1989). Thus it is generally agreed that legislating aircraft to meet Chapter 3 standards represent one of the last foreseeable major developments in aircraft noise reduction (ICAA, 1990).

It is generally expected that as an increasing proportion of World's jet fleet are converted to Chapter 3/Stage III standards, then the noise in the vicinity of airports would be reduced (FAA, 1986; Airports and the Environment, 1991). The main environmental improvement of reduced noise would be fewer people are disturbed and for those who are affected the level of nuisance would be less (ICAO Circular 218-AT/86, 1989); however elimination of total noise will not be achieved.

It is necessary to say that this operating ban on certain aircraft will affect the air transport industry as a whole in different ways, depending on the number of countries and airports that introduce this form of restriction. It is evident that the imposition of strict international standards to meet Chapter 3 requirements from Chapter 2 will cause financial difficulties for airlines especially those from developing countries. This is also very much the case for financially vulnerable airlines.

At present ICAO is considering a new set of proposals to establish standards that go beyond the current Chapter 3 noise certification (Avmark, 1995). Analysts' contend a move to a more stringent standards now would have detrimental effects on the industry. The result would be a disproportionate economic harm compared to the environmental improvements it secures. ICAO Circular 218-AT/86 (1989), discusses in detail by aircraft type i.e. narrow-body, wide-body, the economic implications of future noise restrictions on subsonic jet aircraft.

Noise is difficult to legislate against and complicated to monitor efficiently (Airport International, 1986) as has been demonstrated at German airports, who planned to clamp down on airlines that declare Chapter 3 concessions but emit Chapter 2 noise levels (Interavia, 1992). Certification despite being widely used for noise control purposes, there are arguments that this process is misleading and a tool that is used out of context for controlling noise at airports.

Smith (1982) points out that although certification is directed at source noise, by ensuring the latest control technology is applied economically in a reasonable manner, it is too divorced from operational reality. For example one of the major criticism of the certification process is that the levels finally derived are at fixed points with respect to the operation. This does not reflect community locations around large and small airfields.

However the closest standards to uniformity are those that deal with noise at its source in aircraft certification i.e. ICAO Annex 16 and US FAR Part 36 (Spencer, 1990). Most nations have adopted the regulations led by the international agencies and where necessary individual airports have devised their own control measures based on local community exposure patterns (ICAO, 1971).

3.3 Control of Airport Noise Impact

Noise control can be summarised as a combination of actions taken to contain noise at its source within a reasonable economic and technical limits (via certification) and then, as a separate exercise to minimise impact once an aircraft is in service (Smith, 1991). Most countries have either suggested or implemented policies to reduce the exposure of population in areas around airports (Feitelson, 1989). In this section the various important policies that are adopted by airports to reduce noise impact is revised with a possible critique of their effectiveness.

3.3.1 Curfews

Curfews limit the hours in which an airport may permit flight operations to occur. Generally curfews are based on time use of airports but it can also be based on the engine type of aircraft (Hardman, 1982). Night curfews exist at many airports throughout the world and it varies substantially between airports. At some airports, there is a complete ban on all operations while at others only aircraft which have low noise characteristics are allowed (Ashford, Stanton and Moore, 1984).

Curfews are considered by the aircraft industry to be the most severe form of noise control (Bragdon, 1987). The ripple effects of curfews are not isolated events since air transportation involves multiple time zones (Helms, 1982). Scheduling of flights involves taking into consideration complex factors such as demand, departure and arrival times, number of duration of stops, types of aircraft, and its speed (Schoennauer, 1969). Thus night curfews add to the difficulty of obtaining ideal solutions to meet the specific demand. This is demonstrated by the UK Department of Transport Consultation Paper for revised night time restrictions at London airports which reports "if convenient scheduled services on some long haul routes cannot be operated at Heathrow, Gatwick or Stansted, then the competition will move to some other airports such as Charles de Gaulle, Schipol and Frankfurt where restrictions are less onerous".

Despite the associated problems with night curfews, it is very effective in limiting night time disturbance (Ashford, Stanton and Moore, 1984), it is the most important control on airport and aircraft operations (Abelson, 1977) and the one that receives the most public attention (Hardman, 1982).

3.3.2 Operational Noise Abatement Procedures (NAP)

Several operational techniques used for take-off and approach conditions can attain significant reductions of aircraft noise impact on communities around airports (Ashford, Stanton and Moore, 1984). Figure 3.1 and 3.2 illustrate take-off and approach profiles, which are in certain airports in the USA have become standard procedure (Cline, 1986). Depending on the pattern of housing, a power diminution is applied after take-off to reduce noise to benefit either community A or B. Similarly for landing a descent approach is chosen such that the combination of speed, minimum drag and minimum power results in noise reduction.

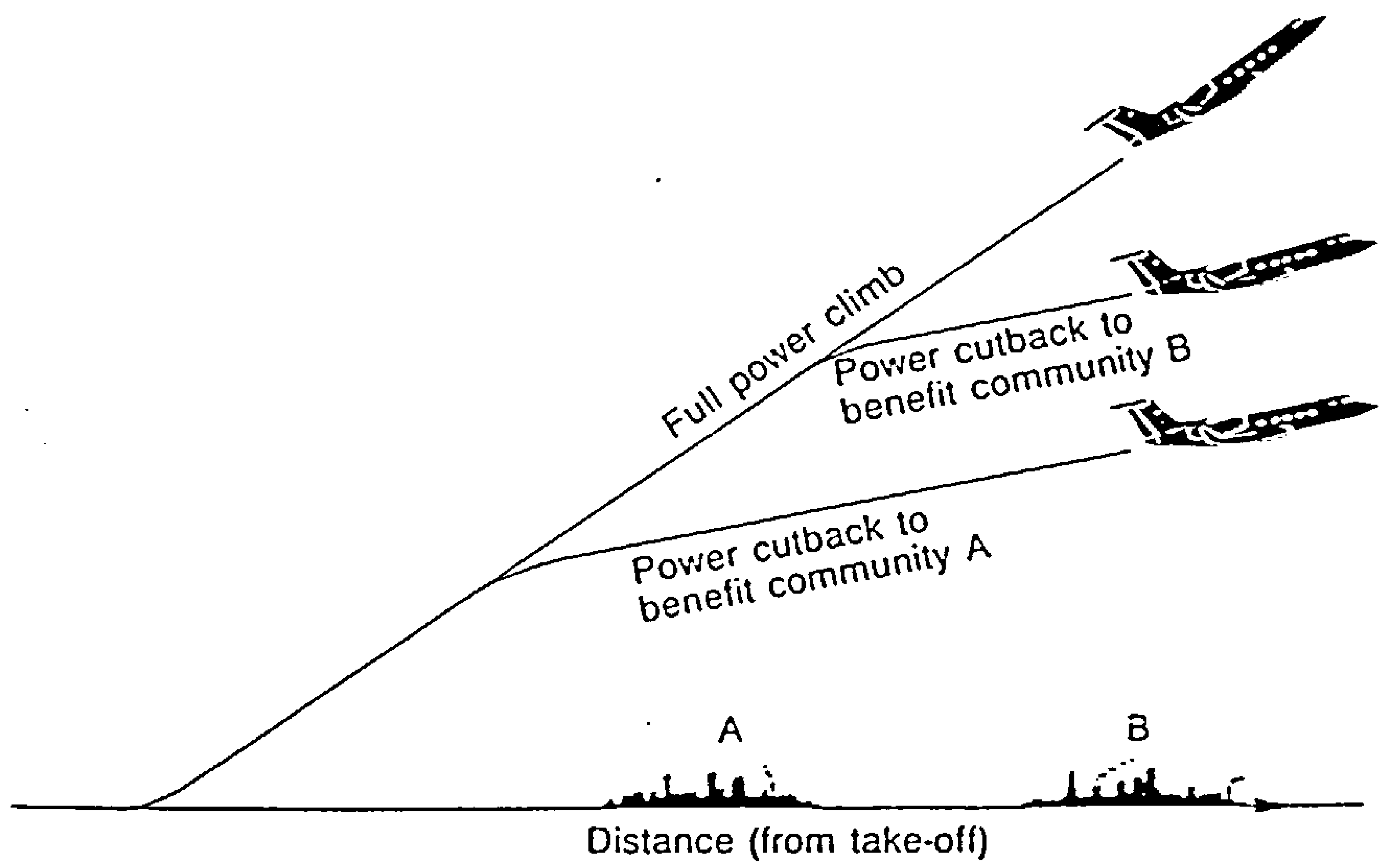


Fig 3.1 Reduction of Take-Off Noise by Engine Power Cutback
(Source: Smith 1989)

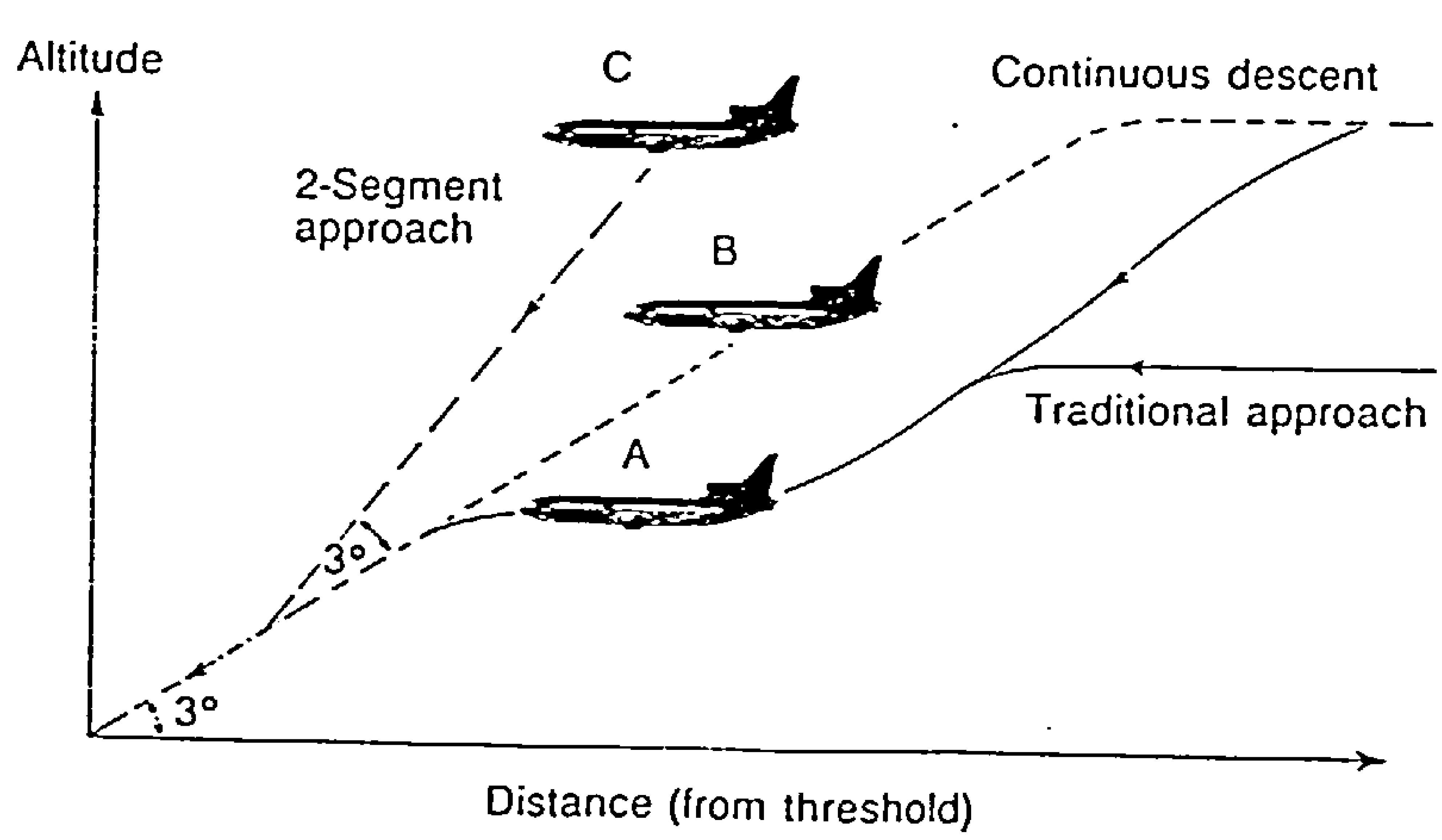


Fig 3.2 Reduction of Approach Noise by speed/thrust/drag Management
(Source: Smith, 1989)

The objective of such a procedure is to minimise noise impact using operational techniques but meeting safety criteria. The pattern of housing under the routes has to be studied in order to determine which course of action to take to reduce noise impact. These kind of landing and take-off procedures have been demonstrated to reduce the size of airport noise contours and most air carriers have adopted such policies where they operate (Bragdon, 1987).

3.3.3 Noise Preferential Runways

This process involves airports specifying a preferred runway to minimise aircraft flights over noise-sensitive areas (Bragdon, 1986). More than a third of US airports have a preferential runway procedure for noise abatement purposes (Cline, 1986). This is the most common operational technique in use and currently twenty six airports throughout Europe are using this system including some of the major ones (Bragdon, 1987).

3.3.4 Minimum Noise Routings (MNR)

Minimum noise routings are very similar in concept to noise preferential runways. The purpose is to route departing aircraft to follow over areas with predetermined low population density. Noise preferential routes are one of the key measures adopted in the United Kingdom to ameliorate the effects of aircraft noise. This practice was decided as one of the best course of action from the airport communities view point, from as early as 1971 by the Noise Advisory Council (Ashford, Stanton and Moore, 1984).

3.3.5 Slots and Capacity

These are limitations on the number of aircraft operations that can be allowed within a specified time period, or on a passenger limit (Bragdon, 1986). The number of slots can be related to aircraft performance, with the airport having a maximum noise budget or quota (Noise Regulation Reporter, 1986). The proposed revised night restrictions for the London airports is based on this principle. It is designed to encourage the use of quieter aircraft by making noisier types use more of the quota for each movement (Department of Transport UK Consultation Paper, 1993), however operators have flexibility to choose between less movements by noisier aircraft or more movements by quieter ones. For example at London Heathrow the proposed summer night noise quota is 7000 and for Gatwick 9000 movements for 1993.

3.4 Land Use Control Regulations

Even if all aircraft are as quiet as technology can make them, and all possible operational techniques are used, the area around a major airport will still be subjected to noise levels that are unacceptable for dwellings (OECD, 1980). Development of land use control can be an effective way to minimise population exposure around airports. Land use control related methods are many; however the systems implemented around airports fall into two categories: direct control by purchase of land or easements on it; and indirect control by zoning, often as a special case in a normal regional planning scheme. Galloway and Bishop (1970) developed a Land Use Compatibility Guide in the United States which noted "land use recommendations are based upon experience and judgmental factors without regard to specific variations in construction and in other physical conditions", and that the recommendations should be consistent with local social, economic and political factors.

In a survey of a sample of 402 US airports, zoning, comprehensive planning and land acquisition were found to be the three leading measures of land use control (Cline, 1986 and Bragdon, 1986). Land use measures have been applied throughout the world, however European countries generally have been more successful in applying these controls compared to the United States (Bragdon, 1987).

3.5 Other Types of Measures

The other types of measures adopted at airports to control noise impact are flight training restrictions, displaced landing thresholds, noise monitoring and within land control regulations, comprehensive planning, zoning, land acquisition amongst others. Noise related charges are another type of measure adopted by airports to control noise impact. The basic philosophy is that the aircraft operators should pay a fee proportional to the noise they generate. The operators of noisier aircraft are financially penalised while the airlines with quieter aircraft are rewarded by reduced landing charges (Bragdon, 1987). There are as much as 27 airports in Europe exercising a noise based charge system (Sellman, 1986) and it is anticipated that this will become more widespread to reflect environmental concerns (Carter, 1991).

Noise related landing charges are discussed in detail in the next chapter. The various types of noise related charges are reviewed with the arguments for its development.

3.6 Summary

This chapter has reviewed the current state of aircraft noise control technology and described the methods adopted by airlines to control noise at source as a result of noise regulations such as the International Noise Certifications. The implications of noise certification has also been briefly discussed together with the criticisms, that it is misleading and distant from operational reality. Carter (1991) says "it is not really surprising that environmentalists distrust any moves made by airlines or airports. Many people living near airports would have thought Chapter III means quieter than Chapter II, but when they observed DC10s and 747s causing more annoyance than smaller Chapter II twin jets, they understandably felt cheated."

Despite the criticisms of certification as a process of aircraft noise at source, it has been identified as the single important measure adopted uniformly throughout the United States and Western Europe to control noise (Spencer, 1990).

The other important measures adopted by airports such as night curfews, Operational Noise Abatement Procedures (NAP), Noise Preferential Runways (NPR), Minimum Noise Routings (MNR), Slots and Capacities and Land Use Regulations, are reviewed with their possible criticisms.

The noise related landing charge has been briefly mentioned. The full discussion on this subject is covered in the next chapter. Chapter five then shows how the noise landing charge is developed for the selected airports.

POLLUTER PAYS PRINCIPLE AND THE NOISE LANDING CHARGE

4.1 Introduction

This chapter covers numerous topics which prepare the grounds that lead to the development of the noise landing charge in the next chapter. First the Polluter Pays Principle (PPP) as a policy, the basis on which it is found and the necessary interpretations to reflect environmental concerns are discussed. A number of methods are available to serve the PPP, the approach taken in this study is described and its relevance is reviewed.

The noise charge as an alternative tool of the Polluter Pays Principle, its advantages over the regulatory methods are analysed. The various noise charges that already exist and the reasons for adopting the damage related charge in this study are also examined.

In order to apply the Polluter Pays Principle with the methodology chosen in this study, it is necessary to value the cost of aircraft noise around airports. The various methods of aircraft noise valuation and their reliability are reviewed.

4.2 The Polluter Pays Principle

It was during the 1960's in the United States, that the idea of actually constructing and implementing pollution taxes was advanced to the level of active policy consideration (Kneese and Bower, 1968). In the early 1970's it was taken up by the Environment Directorate of the Organisation for Economic Co-operation and Development (OECD) and here it emerged as the "Polluter Pays Principle" (OECD, 1975).

An externality is defined as an effect of one economic agent on another that is not taken into account by normal market behaviour. Aircraft noise in economics literature is described as an externality (Ollerhead, 1973). For example Muskin and Sorrentino (1977), refer to airline noise as an externality in the sense that it effects communities around airports. This is an activity for which the communities are not directly involved for the economic productivity of the airline.

The relevance of Polluter Pays Principle in this study is that the principle is set on internalisation of externalities, and aircraft noise is treated as an externality. Pearce and Edwards (1979) mentions "Polluter Pays Principle speaks of internalising the cost of pollution prevention and control measures determined by public authorities." Also OECD (1975) makes an important distinction, "Polluter Pays Principle means that the cost of avoiding, eliminating and compensating for environmental pollution must be included in the costs met by the economic transactors concerned", and this process is referred to as internalisation of external costs.

The Polluter Pays Principle is now fairly familiar in policy circles (Pearce, Markandya and Barbier, 1989) and interpretations on the guiding principles are described in OECD's analysis and implementation document (1975). As outlined by OECD, the Polluter Pays Principle means that prices should reflect marginal social cost (MSC) where the marginal external cost (MEC) component of MSC has been evaluated in monetary terms.

4.2.1 Mechanisms of The Polluter Pays Principle

The two basic mechanisms for making the polluter pay are by:

(i) setting standards

(ii) setting charges or taxes

Setting standards is a mechanism of direct control and is also known as direct regulatory approach towards environmental policy. This type of policy method involves the polluter complying with regulations directly enforceable by legal measures and not through the operation of economic incentives.

The direct regulatory approach of environmental policy is the most traditional, widespread and tested approach (OECD, 1980). The objectives of this method are clearly determined, without depending on the economic mechanisms and definitely the surest means of preventing irreversible effects or unacceptable pollution. Thus there are certain definite advantages associated with this method, however there are also drawbacks. Direct regulations are increasingly felt to be static, inflexible and suboptimal in terms of environmental and economic efficiency (OECD, 1989). The drawbacks are discussed in detail by Anderson, Kneese, Reed, Taylor and Stevenson (1977) - only some are presented below.

> The direct regulatory approach can be cumbersome to administer, expensive to arrange for checking, measuring and to sanction.
>
> Economic efficiency is reduced, since no economic mechanism exists to enable the standards to be attained at least cost
>
> Direct controls are not incentives, since it does not activate the polluter to do more or less other than to comply with regulations
>
> Issuing pollution permits or the right to buy pollution can be discriminatory in the sense that selling to a minority the right to harm the majority.

It is the charging mechanism of Polluter Pays Principle which is of interest and relevant to this study. This is an instrument of the economic approach and the objective is to remedy the drawbacks of direct regulatory approach, by providing flexibility and motivation while enabling some objective to be achieved at least cost to the community (OECD, 1980).

The economic approach is based on incentives rather than regulatory constraints, the idea is to progress in such a way that the polluter responds to an economic signal, by creating a "pollution market". The various instruments used to advocate this are the sale of pollution rights, payments and charges. Sale of pollution rights and payments have never been practically used in the airline industry for noise management and OECD (1980) writes "these two methods are largely of theoretical interest".

4.2.2 Definition of Pollution Charge

A pollution charge may be defined as a tax based on polluting emissions or on disamenities expressed by some appropriate method of measurement (OECD, 1980). The optimum rate of charge t* in figure 4.1 is achieved when the marginal cost of abatement curve intersects the marginal social cost curve, that is the marginal damage cost curve. Reductions in pollution level less than C, implies cost of abatement exceeds the benefit of that extra abatement. Therefore at level C the pollution level is optimum.

Figure 4.1 shows that when the charge rate is optimal, this enables the cost of any pollution related damage to be totally internalised. That is marginal external cost has been incorporated into the marginal social cost. At rate t* the polluter bears an overall cost equivalent to area Ot*AB, which can be broken down into three parts. Area CAB representing the cost of treatment; that is the excess cost required to treat beyond the optimum level of pollution. Area OAC represents the cost of residual damage corresponding to pollution OC. The area Ot*A may be regarded as a tax on the use of environmental resources.

The charge induces the polluter to reduce pollution to a point where the unit rate of charge equals the marginal cost of treatment; beyond this level it is cheaper to pay the charge than to continue abatement. The higher the charge the greater the incentives.

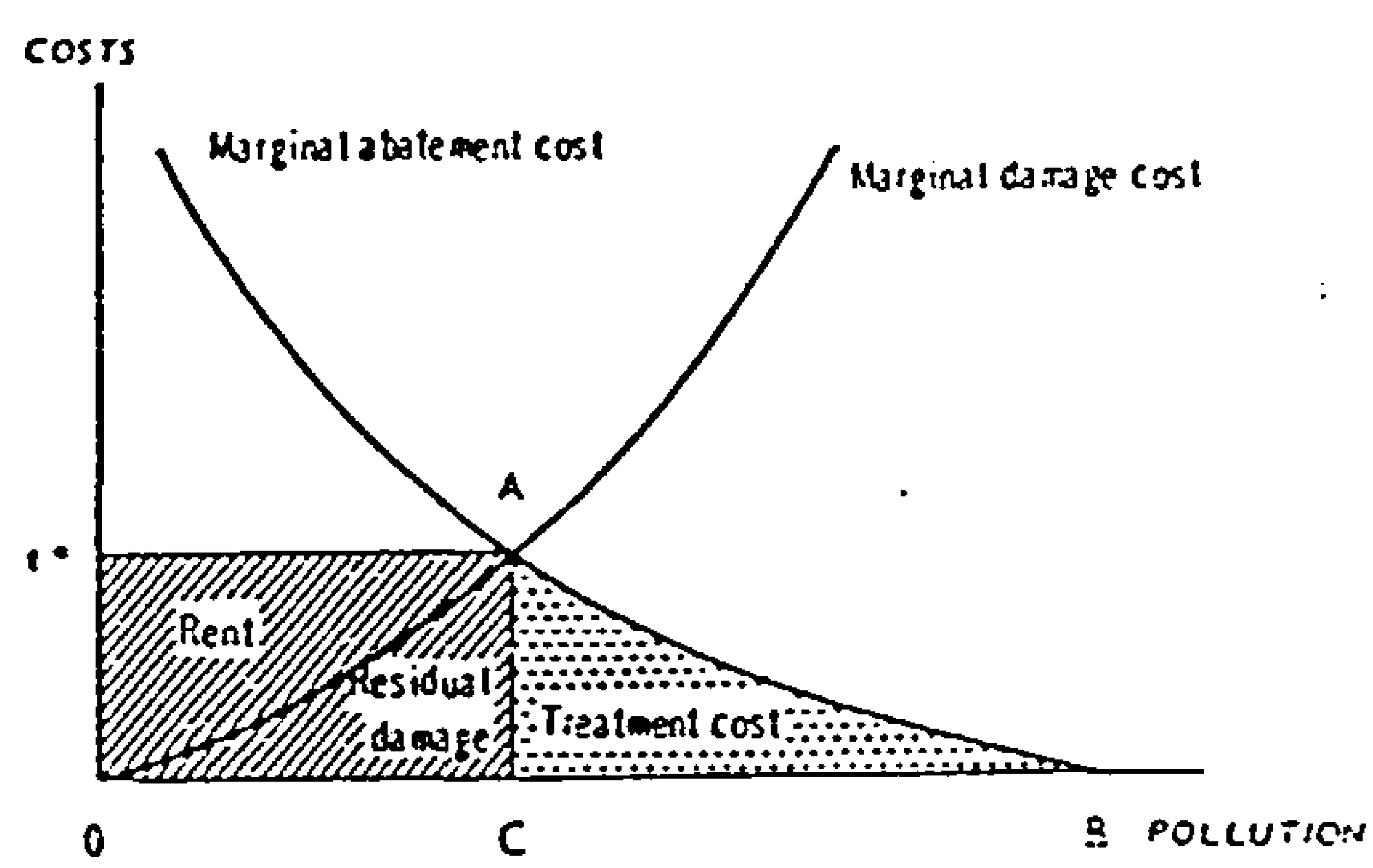


Fig 4.1, Source: OECD, 1980

Pollution charges as an instrument to the economic approach offers many advantages and enjoys wide support among economists (OECD, 1975). Some of the favourable advantages are:

The charge obliges the polluter to bear the cost of the damage

The charges are flexible and effective, since it allows each polluter to choose and combine the course of action which enables profit to be maximised

The charges are an incentive since it encourages reduction of pollution level

Baumol and Oates (1971) made the proposition that charges often produce lower compliance costs. That is the cost polluters bear in meeting the standard is lower than would be the case if the standard was simply set and polluters were legally obliged to adhere to it. This is because charges enable the polluter to choose how to adjust to the environmental quality standard. Polluters with high costs of abating pollution may prefer to pay the charge, whilst polluters with low costs of abatement may prefer to install abatement equipment.

Pearce, Markandya and Barbier (1989) demonstrate that although the Polluter Pays Principle speaks of making the polluter pay, as with any cost increase if polluters can pass on the increase in costs to consumers, they will do so. However in practice they can only pass on part of the increased costs as explained by figure 4.2.

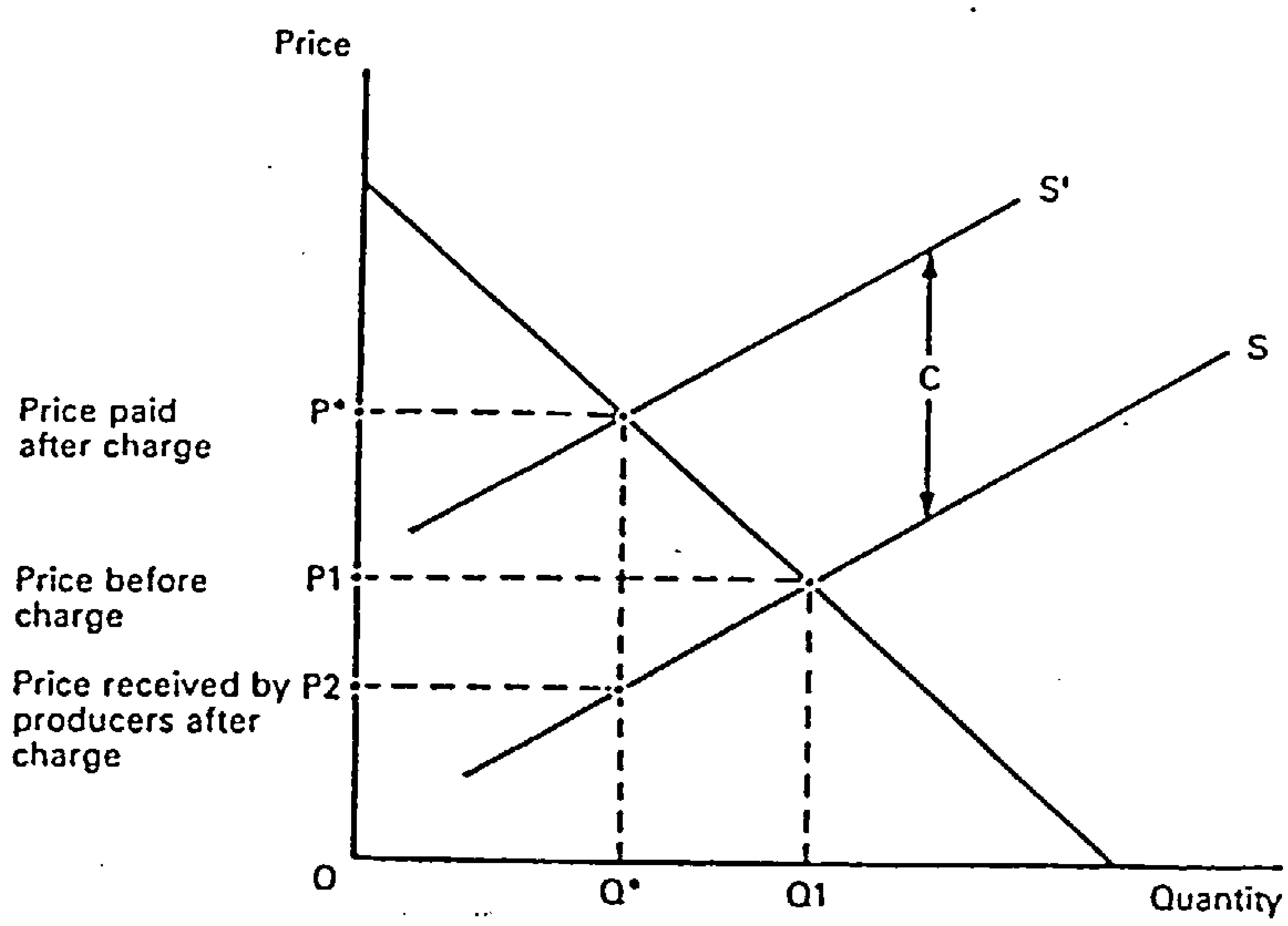


Fig 4.2 Producers and Consumers Share Cost of Pollution Control
(Source: Pearce, Markandya and Barbier, 1989)

Figure 4.2 shows a supply curve, S, and a demand curve D. When a pollution charge C is applied, it raises the polluter's costs and causes the supply curve to rise to S'. The new market price is P*. Consumers pay this price in the market but out of it polluters are made to pay the charge component C, thus the price received by polluter is actually P2. Polluters have born some of the cost of the charge and so have consumers. The exact relative contributions of polluters and consumers depends on the slopes of the S and D curves. Generally more competition in the market, the less will consumers bear the burden of the pollution charge.

This section has reviewed the Polluter Pays Principle and discussed the mechanisms used to require the polluters to pay for the pollution. The advantages and disadvantages associated with the two broad mechanisms have been presented. It is found that the pollution charge mechanism is a favourable tool amongst the economists and gaining wider acceptance. The reasons for the cost increases passed on to the consumers have been discussed.

The relevance of noise landing charge with Polluter Pays Principle is that the landing charge can be used by airport authorities to make airlines pay for the environmental damage they cause; in this case by the aircraft noise to the communities as an externality. Throughout many airports in the US and Europe noise charges are already in effect and the "polluters must pay" principle is becoming more likely to target aviation industry, not only for noise pollution but also emissions pollution (Alamdari and Brewer, 1994). However the charge may not be optimal in any sense.

The research area identified in this thesis is based on the structure of the Polluter Pays Principle described in this section. The noise landing charge developed in the next chapter is analogous to the pollution charge which economists advocate. In chapter six an airport choice model is constructed which determines the consequences of the landing charge on passenger's choice of airports, based on the concept described in this chapter that polluters will pass on the costs to consumers where possible.

The next section looks at the possible advantages associated with noise charges in comparison to regulatory methods for noise management. The previous noise charges that have been used are reviewed. For the landing charge developed in this study, noise as an externality has to be monetarily valued. Therefore the various methods to value aircraft noise are examined and their criticisms are reviewed.

4.3 The Noise Charge

In the previous chapter most of the important tools of direct regulatory approach such as the ICAO Annex 16 and FAR Part 36 Certification standards, curfews, operational noise abatement and others were discussed. There are a number of direct advantages associated with the regulatory mechanism of noise abatement, they are:

Regulations contain noise standards that become effective at a series of future dates, this allows time for airlines, manufacturers to adjust accordingly

Regulations clearly define the overall aim of achieving environmental quality

Provide manufacturers with adequate lead time as well as incentives to develop new and improved methods of noise reduction at a lower cost

Although regulatory approach having some definite advantages, advocates for the economic approach indicate that the regulatory standards such as those of ICAO do not adequately ensure satisfactory protection of the health and well being of persons exposed to the noise (OECD, 1986). It has been pointed out that regulatory standards of ICAO do not define noise levels acceptable to the public but the lowest noise levels estimated technically feasible and economically reasonable for aircraft manufacturers. The annoyance created around communities is a function of individual aircraft movement as well as the total number of aircraft movements. The standards do not take into account the frequency of aircraft movement, and the fleet renewal cycles are too long (OECD, 1980 and 1986).

Airport noise reduction through regulations have been crude and inefficient (Nierenberg, 1978). Others such as Alexandre and Barde (1987) have argued that regulations can be static and provide little incentive for innovation. They are often formulated after lengthy negotiations, updating standards are slow and infrequent and frequently reflect the "line of least resistance" i.e. they reflect the needs of the least efficient operators.

Nierenberg (1978) pointed that regulatory controls depends on compliance upon the threat of mandatory requirements, which can impose severe economic penalties upon airlines and air travellers. As a result airlines tend to resist the imposition of these standards or try to delay their application. This may cause regulators to back down rather than enforce the standards making application uncertain.

Due to the shortcomings and limitations of various other noise management tools have led many countries to consider the use of noise charges to induce faster turnover to quieter aircraft, to finance mitigation effects such as insulation and purchase of houses in noise stricken areas (OECD, 1986).

In economic terms aircraft noise is regarded as an externality, which produces social costs (Alexandre and Barde, 1987). In the neo-classical tradition in environmental economics, the use of a charge on polluters in order to correct for the misallocation of resources, brought about by the existence of uncompensated externalities is encouraged (Alexandre Barde and Pearce, 1980). Noise charges are defined as a payment to the relevant authorities for each unit of noise above a certain level emitted into the environment (OECD, 1980).

According to economic theory, a noise charge is optimal if the rate is such that it exactly compensates for the social cost of nuisances at the level where the marginal social cost equals the marginal control cost (Alexandre and Barde, 1974). Marginal control cost refers to the cost for an extra unit of noise reduction and marginal social cost refers to the cost to the society due to an extra unit of noise increase.

Figure 4.3 shows that the optimum noise level is found at N*, where the marginal social costs equals the marginal abatement costs. A further noise reduction from N* to N would not be collectively beneficial since the abatement cost exceeds the damage cost i.e. costs exceed benefits. Thus if point N* is known, a charge at a rate r, can be determined which would automatically induce a noise reduction to level N*. Figure 4.1 earlier showed the optimum pollution charge. Although similar in concept figure 4.3 shows more specifically the optimum noise charge.

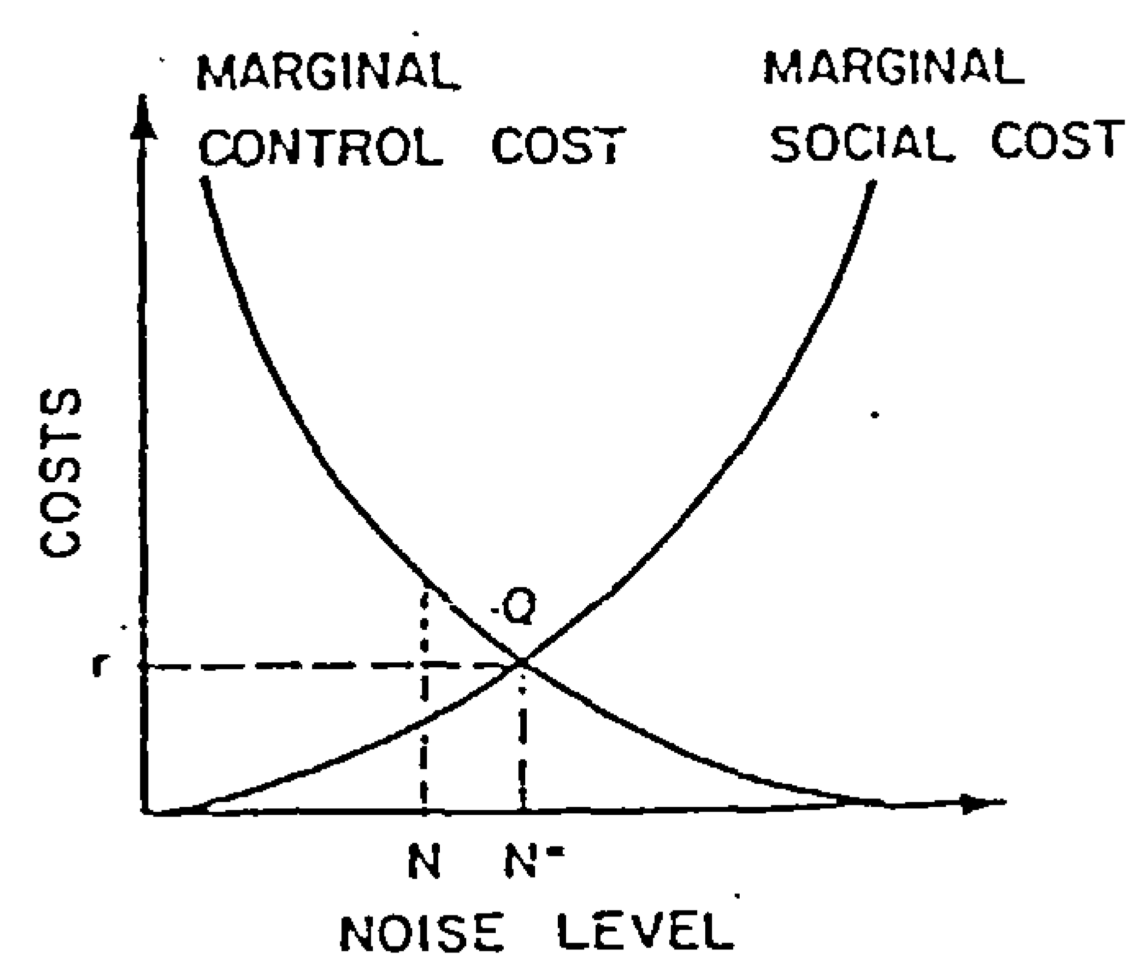


Fig 4.3 Optimum Noise Level
(Source: Alexandre and Barde, 1974)

Aircraft are already subject to landing fees at airports, and in many countries such as in the Netherlands, France, Switzerland, Japan, Germany and the UK (OECD, 1978 and 1980) noise charge schemes operate as an additional landing fee. All the different noise landing charges will be reviewed in this section, however it is appropriate to discuss the advantages associated with noise charges as an economic approach of the Polluter Pays Principle for noise management.

Amongst the literature that deal with environmental economics, the advocates of noise charges are many. Walters (1975) writes "the great attraction of charges compared to direct regulatory approach is that it leaves airlines, airport owners and the passengers to make their own choices. Policy issues should be such that charges should reflect the costs on the community and if the landing charge reflects the money value of the disbenefits, then after a suitably long period of adjustment the correct mixture of quiet and other goods would be produced."

OECD have carried out extensive research on noise charges of various types. OECD's findings conclude that charges would complement the regulatory measures for noise control, and this corresponds to an earlier finding by the Council on Wage and Price

Stability (COWAPS, 1977) USA. This report concluded that noise charges would be more cost effective, produce more quiet for less money than regulations because it provides monetary incentives for the airlines to voluntarily adopt less noisy practices in order to reduce their noise charges. The Council specifically noted charges would be less disruptive to interstate commerce than imposing curfews or grounding noisy aircraft.

OECD have identified a number of advantages with charges, they are:

> The charge if set at a sufficiently incentive level, could encourage airlines to retrofit aircraft that are not certified by ICAO
>
> Airlines would be encouraged to renew their fleet of aircraft more promptly and to purchase quieter machines
>
> The charge would constitute a permanent incentive towards developing quieter aircraft
>
> At operational level, airlines could be induced to use less noisy aircraft on short haul busy routes involving large numbers of landings and take-offs and the noisiest types on the long haul routes where the number of turnarounds are less.

There does not appear to be any major criticisms of the noise charge approach however, OECD (1978) point out charges should be high enough to ensure proper achievement of the objectives, otherwise charges would be considered ineffective or as a "license to pollute". Rates on the other hand should not be so high that airlines are confronted with economic hardships.

Another advantage with noise charge is that it can serve as a redistributive function for noise control programmes. The funds can be redistributed for various purposes such as sound proofing, compensating and protecting local residents, buying land for noise mitigation. Experience shows up to now the redistributive function is prevailing (Alexandre, Barde and Pearce, 1987).

Several countries as previously mentioned have already implemented or intended to implement noise charges. The following section reviews the aircraft noise charges that have been in use. Amongst all the literature on noise charges OECD (1986) and Alexandre, Barde and Pearce (1987) are the most recent authors, to discuss the various charges. Therefore the charges reviewed here have been extracted from their publications.

Noise charges fall roughly into three categories: revenue generating; compliance related and damage related (Nierenberg, 1978). Each of these categories are described with examples.

4.3.1 Revenue-Generating Charges

This category of noise charge is designed mainly to generate revenues to be used for noise reduction purposes. Such fees at Japanese airports provide funds to finance sound proofing or to relocate families. The overall charge levels are determined by the cost of the measures taken to reduce airport noise exposure. The charge is a function of aircraft weight and the noise level according to the formula:

Charge = 290B + (EPNdB taking off + EPNdB landing) - 83/2 x 1630 (yen)

where B is the maximum weight of aircraft in tons

In the Netherlands, a charge was put into effect since 1983 based on meeting standards set by ICAO certification. The charge was computed for aircraft weighing more than 20 tonnes, using the formula:

$$T = f \times n \times 10 \frac{(L_r - 270)}{45}$$

where:

f = the charging rate

n = an equalisation factor to make the noise levels as measured according to ICAO and FAA (USA) procedures comparable

L_r = the sum of the noise levels at the three ICAO measuring points

The charge for uncertified aircraft i.e., those that do not comply with ICAO standards is computed as follows:

$$T = f \times k \times W^{2/3}$$

where:

k = constant depending on the noise category of the aircraft (e.g. 0.15 for the quietest aircraft and 0.9 for the noisiest)

W = maximum permitted weight

In France in 1983 it was decided to develop a noise charge which would link the landing fee with the noise levels emitted by aircraft. The application of this charge was in effect from 1987, where aircraft were classified in one of five groups:

Category	Nominal landing fee
V	minus 10%
IV	landing fee
III	plus 5%
II	plus 10%
I	plus 20%

Group V represents the quietest aircraft to group I representing the noisiest aircraft.

4.3.2 Compliance-Related Charges

This type of noise charges are intended to achieve compliance with established noise standards. Charges are set at the point where airlines have a financial incentive to achieve noise abatement standards by using quieter aircraft. In Germany a reduction of the landing fee is granted for aircraft complying with the ICAO Annex 16 standards. For example at Frankfurt International airport a 30% noise charge discount is levied between the ICAO Annex 16 Chapter Two and Chapter Three aircraft (Interavia, 1992). In the United Kingdom, Manchester airport has been using a system of rebates since 1975 and currently aircraft that exceed the defined noise level of 100 PNdB at night and 110 PNdB at day, are subject to a 50% additional fee on their landing charge.

Another approach bases the charge on reliable noise impact indicator and calculates the rate according to the cost of a predetermined program of local noise abatement measures around the airport applying the charge (for example, purchase of land or insulation of buildings). Knowing the noise footprints of aircraft and air traffic volume, it is possible to devise an Aircraft Noise Overall Impact Index (ANOI) based on the hypothesis that loudness doubles for each 10 dB increment (Alexandre and Barde, 1974). Surveys have shown that every 10 dB increase of noise level produces a twenty-point increase in the percentage of people intensely annoyed.

These findings combined in an impact indicator to give the formula:

$$I = 2(L_i - L_n) \times 2^{(L_i - L_n)/10}$$

where:

I = impact indicator,

L_i = noise level

L_n = annoyance threshold

Thus the ANOI index would be =

$$\sum F_i PD_i I_i$$

where:

F_i = noise footprint of an aircraft at noise level i (in ha. or km^2)

PD_i = population density in F_i

I_i = impact indicator in F_i

The rate of the charge (α) would be calculated by dividing the cost of local abatement at this airport by the number of ANOI units produced at the airport. Each aircraft would then pay a charge for each landing or takeoff equal to

$$\alpha_i \text{ ANOI}_i$$

This noise charge based on annoyance is closely related to a damage related charge. However, Alexandre and Barde (1978) argues it does not entirely reflect the nature of damage related charges. It is pointed out that the ideal solution is to calculate a charge that is a function of actual cost of damage caused by noise expressed in monetary terms. Studies carried out at the OECD (1980), COWAPS (1977), Walters (1975), Nelson (1978), Alexandre, Barde and Pearce (1980) show that it is possible to introduce a system of aircraft noise charges based on this methodology.

4.3.3 Damage-Related Charges

This charge is based upon estimates of the damage caused by airport noise. Based on the noise emission of each type of aircraft measured in EPNdB a charge can be computed for each aircraft. The social cost of aircraft noise is computed using the formula:

$$SC = V\,H\,N\,M$$

where:

SC = the social cost of aircraft noise
V = the average property value per residence within the 35 NNI contour
H = the number of households affected by aircraft noise
N = the average number of NNI to which people are exposed
M = the property value depreciation rate caused by aircraft noise.

This is the only formula that attempts to incorporate in it the social cost of aircraft noise relating it to house price depreciation. The critical assumption is that depreciation represents a monetary evaluation of the social cost of noise. With this method of noise charge controversy persists, whether the house price depreciation can be a reliable estimate of social cost. However a vast amount of literature has developed on this subject since the early 1970's (Dygert, 1973) and only as recently as 1994, Levesque carried out research investigating the effect of aircraft noise on residential housing markets.

The noise landing charge developed in this study is based on this methodology of damage related charge. The credibility of this type of charge hinges primarily on two factors. Whether hedonic price mechanism can be trusted as a technique for evaluation of social cost of noise and the depreciation rate (M) of the property value with noise level.

A number of research has shown that it can be used as a reliable method of measuring social cost of aircraft noise. The next section discusses the methods used for measuring the cost of aircraft noise and an estimation of the depreciation rate which will be used in the landing charge.

4.4 Measuring The Cost of Aircraft Noise

Primarily there are two approaches to measuring the cost of aircraft noise: the exclusion facilities approach and the house price differential or "hedonic" approach. Both are described below and reasons for adopting the hedonic method of noise valuation are assessed.

4.4.1 Exclusion Facilities Approach

The exclusion facilities approach was originally developed by Starkie and Johnson (1975) and the method relied on observation that people exposed to noise freely incur expenses to protect themselves from such inconveniences. An example is the installation of double glazing by householders. Starkie and Johnson suggests this action reflects a willingness to pay for quiet. In this example it can be assumed that the householder will choose to purchase noise protection facilities if:

$$G < N\text{-}N'$$

where G = cost of the window installation, N = the subjective valuation of the total noise without insulation, and N' = the subjective valuation of the noise after insulation. House holders will purchase exclusion facilities when the benefit of noise reduction N-N', exceeds the cost of protection G, and they will continue to be motivated to purchase sound insulation until,

$$XN\text{-}XN' = \text{“}X\text{”}G$$

where "X" is a small or marginal change. The cost G therefore, is an expression of the willingness to pay for noise reduction. Empirical results obtained by Starkie and Johnson using surveys and regression analysis for UK Heathrow International Airport indicate a willingness to pay for insulating a five-room house (providing an average 14 dB(A) reduction) of about 5% of income.

The exclusion facilities approach suffers from a number of deficiencies. Alexandre and Barde (1987) argue that, people exposed to noise may choose to relocate to another less noisy area instead of insulating their houses. Therefore the cost of moving, the financial loss incurred by selling the house which may have a reduced value due to the noise and the loss of consumer's surplus should be taken into consideration. Thus provided insulation serves no other purpose, this model applies only for those who stay in the noisy area and provides a minimum estimate of the social cost of noise.

Another reason why this method may under estimate the social cost of noise, is due to the fact insulation does not affect the noise exposure of balconies and gardens and does not remove indoor noise altogether. It ignores the social cost of this "residual noise". On the other hand there is a countervailing factor, that insulation devices such a double glazing provide additional benefits in terms of thermal insulation and security. This may give an element of over estimate of the social cost of noise. In summary this approach although relatively simple, as shown by Pearce (1985) it provides only an average valuation of noise reduction and not a marginal valuation.

4.4.2 The House Price Differential Approach

The hedonic price estimation has been the most widely applied technique to estimate the effects of environmental influences on the determination of house prices (Pennignton, Topham and Ward, 1990). The idea underlying this method is that, the value of a house depends not only on its intrinsic characteristics such as the number of rooms and garages etc., but is also a function of a number of other environmental attributes such as location, accessibility, proximity to schools, shops and pollution including noise. Therefore the value of a house is among other factors a function of noise. With the use of statistical techniques to identify how much a property differential is due to a particular environmental difference, in this case aircraft noise between properties is referred to as the hedonic approach.

Over the last twenty years various studies have explored the possibility of aircraft noise affecting the prices of residential properties. Using the hedonic technique Walters (1975); Pearce (1978); Nelson (1980); O'Byrne, Nelson and Seneca (1985); Pennington, Topham and Ward (1990); and Uyeno, Hamilton and Biggs (1993) there appears to be a consensus view that aircraft noise has a small, negative but statistically significant effect on house prices.

Pennignton et al (1990), with research based around Manchester International Airport was the exception, finding that aircraft noise had a low negative but weak relationship with house price differential. This view has been challenged by Collins and Evans (1994), who demonstrated that aircraft noise does have an effect on residential property values using Artificial Neural Network technique with the same data. Although this result confirms that aircraft noise has a negative impact on residential properties but a question is raised regarding the reliability of the hedonic method of evaluating the cost of aircraft noise.

The hedonic approach suffers from a number of criticisms, some relate to the assumptions while others to the practicality of the method. The criticisms are discussed at the end of this section. However there does appear to be a consensus view among those who have used this technique Levesque (1994), OECD (1989), Pearce, Markandya and Barbier (1989) that it can be used as a reliable method of evaluating the monetary cost of aircraft noise.

Most of the research find the value of the rate of depreciation of house price with unit increase in noise level to be in the range of 0.5 to 1.0. Nelson (1980) writes "a survey of evidence from thirteen studies suggests noise discounts in the range 0.4 to 1.1% per decibel dB." Although there are extreme results as shown in table 4.1, where for Toronto a minimum of 0.18% and for New York a maximum of 2.0% of house price depreciation by one unit change of noise level (NNI, NEF).

Location	*Impact of one unit change in NEF*	*Impact of one unit change in NNI*
USA		
Los Angeles	–	0.78
Englewood	–	0.78
New York	1.60–2.00	0.78
Minneapolis	0.40	0.62
San Francisco	0.50	0.45–0.90
Boston	0.40	–
Washington, DC	1.00	–
Dallas	0.58–0.80	–
Rochester	0.55–0.68	–
UK		
Heathrow (a)	0.56–0.68	–
(b)	–	1.12
Gatwick	–	1.46
Canada		
Toronto	–	0.18–0.60
Edmonton	0.50	–
Australia		
Sydney	0.00–0.40	–

Table 4.1 % Reduction in House Price: Comparison of Hedonic Price Studies (Source: Pearce and Markandya, 1989)

Recent findings by Uyeno, Hamilton and Biggs (1993) for Vancouver International Airport in 1987 show a 0.6 per cent depreciation of house values with unit increase in noise level (NEF). Levesque summarises the findings of others "aviation noise appears to reduce prices of otherwise similar houses between 0.5 and 0.6 per cent for each NEF decibel."

As it can be seen the depreciation rate varies between the two extreme values produced by Nelson (1980), depending on the location of the city and the airport. However extensive research done by Pearce and Markandya for OECD (1989) describe the hedonic technique in detail, summarise that "for aircraft noise the average figure for depreciation rate is unity for an unit increase in noise level". They conclude the hedonic technique to be an effective method of showing the impact of environmental factors on property values, particularly for estimating costs of noise pollution.

This view is shred by Alexandre and Barde (1987), they conclude that no valuation technique is perfect and there are pros and cons for each. However with a suitable depreciation rate, the hedonic method can be taken as a useful guide for action.

Based on the above conclusions, the depreciation rate for house values to be used for the noise charge is one for an unit increase of NNI. The landing charge is developed for a number of airports, therefore it is appropriate to use an average figure of one to be consistent.

One major assumption is made in the methodology of the landing charge used in this study. That is the marginal cost of noise is assumed to be constant irrespective of the noise level. That is the depreciation rate (M) of the value of houses is the same whether the noise level changes from 35 to 36 NNI or from 45 to 46 NNI. This assumption itself is a criticism of hedonic approach to noise valuation. In reality this assumption is not supported, it is likely that the depreciation rate increases with noise level, starting from a zero depreciation at a low noise threshold where noise does not affect property prices, e.g. 20 NNI (Alexandre and Barde, 1987).

This has been demonstrated from one of the earliest research of aircraft noise valuation. The Roskill Commissions (1971) valuation of residential noise nuisance, around Gatwick Airport showed that depreciation rate varied from less noisy to noisy areas. Another assumption made for this noise charge is that, all types of houses are taken to depreciate by the same value. This has also been shown by the Roskill Commissions report in the case of Gatwick Airport, that high priced properties depreciated more in value than low priced properties in the same noise zone.

Collins and Evans (1994) using data for Manchester Airport, show that detached house values are much more sensitive to aircraft noise than those of semi detached or terraced houses. Figure 4.4 shows the rate of reduction in value of different property types with increasing noise level measured in NNI. This is one of the few studies that distinguish depreciation rates between house types. In general most of the other studies on this subject have presented noise impact on houses without categorisation, as shown by table 4.1 earlier.

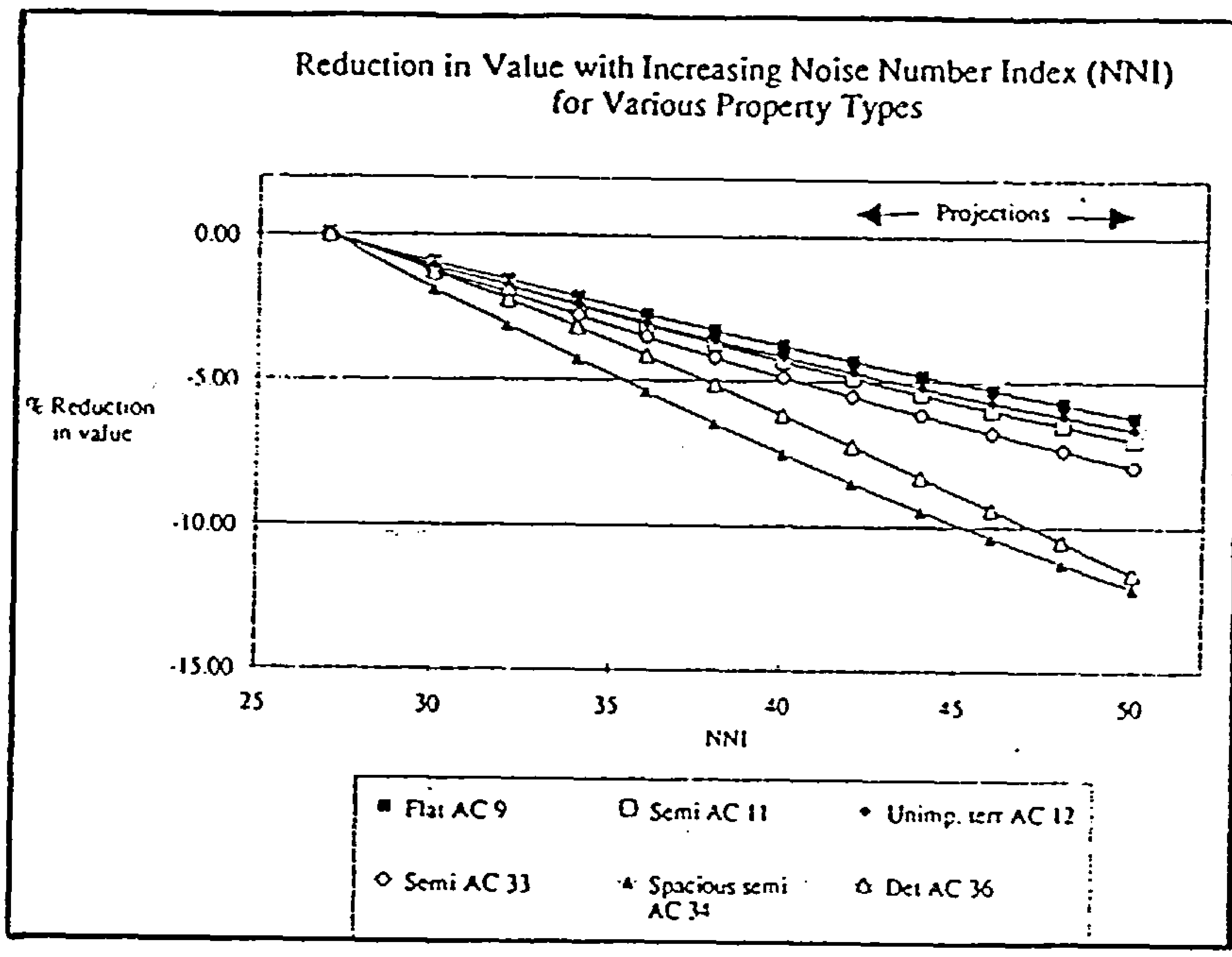


Fig 4.4 Reduction in Value with Increasing NNI for Various Property Types

(Source: Collins and Evans, 1994)

This section outlines some of the other criticisms of the hedonic approach to noise valuation. The hedonic theory is based on two major assumptions, both are subject to controversy. The housing market is assumed to contain no imperfections such that individuals are constrained by anything other than their budget. Of all markets, the housing market is the one in which this kind of assumption is least likely to be met (Maclennan, 1977; Harris, 1978 and Pearce, 1978).

The other assumption is related to the similarity of utility functions (Pearce and Edwards, 1979). This assumes all individuals attach the same value to the various attributes which determine the value of their house. Further all the houses in question must be identifiable and quantifiable. It is unclear in practice whether the set of attributes are similar for different individuals (Maclennan, 1977). Alexandre and Barde (1987) conclude, there are many reasons for individuals' set of attributes to differ. Not only does the perception of noise differ between individuals but also their valuation varies. Nelson (1980) shows that in high income areas value attached to noise is higher. Therefore a mixture of different functions with a number of unknown biases are measured.

4.5 Summary

The Polluter Pays Principle sets the basis for the noise landing charge developed in this study. Amongst various mechanisms of the Polluter Pays Principle, the charge approach is recommended by environmental economists. The charge approach is referred as an economic instrument. It has been acknowledged that the economic instrument can be used to complement the direct regulatory approach to abate airport noise.

The advantages of noise charges are, that when set at an appropriate level it can provide a lasting inducement for polluters to abate noise and also act as a constant stimulus to technological progress. OECD (1980) and others argue it enables noise to be abated at minimum cost to the community. The noise charges can have both an incentive and financing function. The charge should be an incentive up to the level where the marginal cost of noise abatement equals the unit rate of charge. This is because the charge induces the polluter to reduce pollution to a level where the unit rate of charge equals the marginal cost of treatment. Beyond this level it is cheaper to pay the charge than to continue abatement.

Three types of charges have been recognised and the damage related one is adopted in this study, as it is identified with the Polluter Pays Principle. The damage related charge reflects the social cost of aircraft noise. This method of charging system is used in the next chapter to develop the noise landing charge for the selected airports.

The two primary methods of noise pollution valuation in monetary terms are the exclusions facilities approach and the hedonic approach. The methodology of the noise landing charge in this study uses the hedonic approach. There are a few criticisms of the hedonic approach. However the conclusion is that it can be used as a reliable method for noise valuation, provided as Pearce and Markandya (1980) suggest the depreciation rate to be unity for an unit increase in noise level.

The two major assumptions with respect to the methodology of the landing charge have been discussed. The reasons for making use of a unit rate of depreciation with unit increase in noise level have also been identified.

DEVELOPMENT OF THE NOISE LANDING CHARGE

5.1 Introduction

The previous chapter discussed the Polluter Pays Principle and demonstrated the use of damage related charge, which can be taken to develop the noise landing charge. The damage related charge has been identified to reflect the social cost of noise using the hedonic price differential method. This chapter illustrates how the noise landing charge is developed for the chosen airports.

The social cost of noise for take-off and approach are calculated separately for each of the airports. This is to reflect a more accurate assessment of evaluation of the social cost of noise. By evaluating the change in NNI as a result of a flyover of a particular aircraft type, the social cost is calculated knowing the value of houses affected in the noise contour regions.

For each of the airports the social cost of noise is first calculated. The present landing charge based on either maximum take-off weight (MTOW), seating capacity and time use of airport runway, is added to the social cost of noise for each aircraft type to form the noise landing charge. The final section shows the noise landing charge for night time operations based on the assumption that the weighting given to night time flights is ten times as much as day time flights.

Figure 5.1 shows the airports for which the noise landing charge have been developed in this study. The reasons for selecting these airports are:

They represent the busiest airports in England for scheduled international, domestic and charter movements.

The implications of the noise charge in terms of passenger choice of airports will be more realistic, since passengers are likely to change from one airport to another within reasonable access distance.

Data were obtained for these airports. Some were published, others were requested from the departments concerned.

Fig 5.1 Map of the Chosen Airports

Chapter six and seven show how an airport choice model is constructed and the implications of the noise charge on passenger's choice of airport is shown in chapter eight. This chapter demonstrates the necessary procedures for the development of the noise landing charge.

5.2 Calculations of Noise Number Index (NNI)

In chapter two, the Noise Number Index (NNI) was briefly described and the reasons for its use in the noise charge was also given. For the damage related charge, the formula requires the amount by which the NNI changes between the boundaries of two contour levels for example, between 35 and 45 NNI when an additional aircraft flies past. For this to be evaluated, initially the calculations to establish the NNI around an airport need to be examined.

This section describes the standard procedure for calculating the NNI for any airport. By making assumptions to the inputs (i.e. factors that determine the NNI) of NNI the change in NNI is obtained for any aircraft using that airport. Hence the change in NNI as a result of flyover of a particular type of aircraft is used to calculate the social cost of noise, which is then used to develop the noise related landing charge for the airports under study.

Factors required to establish the NNI around an airport are:

(i) The number of aircraft movements disaggregated by type, which constitutes the airport's traffic for the average summer day (0600 - 1800 hours GMT)

(ii) The approach and take-off routes

(iii) The average height profile on departure and approach for every type and class of aircraft

Taken together the above three factors provide a description of the flight paths of all movements on the average summer day.

(iv) The source noise (modified to a noise level at a reference distance of 500 ft)

(v) The maximum noise level (L) of an aircraft at any point on the ground given the flight path of the aircraft and its reference noise level (RNL).

The above factors enable the NNI to be calculated for any airport. How each of these inputs are obtained in practice are discussed below. Some assumptions have had to be made due to limitations of data availability for the calculation of NNI, they are discussed in the appropriate sections.

5.2.1 Number of Movements by Aircraft Type

The number of movements which constitutes the airport's traffic mix for the average summer day are obtained from the airport runway log books. The time period mid-June to mid-September are used for every day of the summer months and an average figure calculated. For this average day the numbers of aircraft and the proportions of aircraft types on every approach and take-off are known.

The annual aircraft movements by aircraft type were supplied by the relevant airport authorities; BAA in the case of Heathrow, Gatwick and Stansted airports. Table 5.1 shows the annual movements by aircraft types for the various airports.

The annual movement figure was divided by the number of days in a year to give the average number of movements per day per aircraft type. Movements for all aircraft types were rounded to the nearest whole number; therefore any aircraft type using a particular airport that had less than 180 movements annually was ignored.

Aircraft and Annual Movements						
Aircraft	Heathrow	Gatwick	Stansted	Luton	Birmingham	Manchester
CONCORDE	1775					
B747	42058	11070	180			2404
B707/720	775	658	186			
ILYUSHIN 86	466					
DC10	3107	5274	919			
MD 11	835					
L TRISTAR	1107	5250				1746
TU 154	2025	439				
B727	5571	3797			800	1536
BAe 146	1593	10881	10643	2158	579	800
B767	30881	8154	582	1017	612	7076
A310	20482	1188		203	180	1512
A300	6199	3284		271		974
F 27	2731	3694	2897	180	1851	
B757	56297	12985	307	2313	1576	19242
TU 134	271					
B737	114724	65884	4087	7280	3252	34248
BAe 1-11	279	9291	7844	1676	11136	12128
DC9/MD 80	50018	6895	884	418	2853	7474
F 28	4102	1578			432	180
F 100	947	1548	3457			
A320	32400	2442		575	184	2146
HERALD	195	831		184	360	
F 50	1269		476		2199	
SAAB 340		3969	714	181	360	
EMB BAND		836	888	182		
SHORTS		6309	620	1178	513	
ATR 42		7066	864			
BAe 748			454			
EMB BRASIL			2014			
BAe ATP				448	2205	
BAe JET					1680	
DASH 7					1062	
DASH 8					213	
L ELECTR				206	330	
DC 8						350

Table 5.1 Annual Movements at Airports for 1992/93

The NNI system takes 80 PNdB as equivalent to zero annoyance. At the time of its development around Heathrow airport, measurement of aircraft peak noise levels of less than 80 PNdB proved difficult because background noise was of a similar level during the passage of an aircraft. Therefore any aircraft type making noise levels less than 80 PNdB were not included. For all the airports this is insignificant, since the vast majority of the aircraft operating make noise levels greater than 80 PNdB and are therefore included.

5.2.2 Approach and Take-off Routes

The landing charge has been developed separately for both approach and take-off, since noise levels made by aircraft varies for the two conditions. For approach all aircraft are assumed to follow over the noise affected areas, a flight path for a standard 3 degrees Instrument Landing System glide slope and along the extended-centre-line of the approach runway.

For take-off, aircraft types are grouped into three: all four-engine aircraft take-off at 7 degrees, all three-engine aircraft at 10 degrees, and all two-engine aircraft take-off at 12 degrees to the horizontal respectively. This assumption reflects to a large extent the operations followed by typical aircraft types. However BAe 146, Dash 7 and L. Electra although four engine aircraft, have been categorised with the two engine aircraft group. This is to keep aircraft in the same size group so that the reference noise level are consistent with other aircraft in the same category.

All aircraft are assumed to follow a climb rate with the prescribed angle with no cut-back over the noise affected areas. With the above assumptions, the average height profile for approach and take-off conditions for every aircraft types can be evaluated using simple trigonometric relationships.

5.3 The Reference Noise Level (RNL)

The reference noise level (RNL) L_0 is defined as the noise level that would be received on the ground directly under the flight path from an aircraft overflying at a height of 500 ft (CAA, 1981). Unlike the certification noise level of ICAO and FAR, there are no standard published figures for the RNL. In practice, the RNL has to be measured on site for any airport and it can vary from one airport to another for the same aircraft types depending on the accuracy of measurement. To simplify measurement, aircraft types are grouped depending on criteria such as number of engines, business jets, commercial jets, turbo props, and maximum take-off weight (MTOW). In general, different aircraft types vary in RNL due to the different number and types of engines although those types with similar engines may have similar reference noise level.

In this study the objective is to develop a landing charge based on the noise level of different aircraft. Hence rather than grouping aircraft types as is done when measuring RNL based on the criterias mentioned above, the reference noise level for each aircraft type was derived from the published certification measured noise levels of International Civil Aviation Organisation (ICAO) Annex 16. The process of deriving RNL from certification noise level is described below.

5.3.1 Derivation of Reference Noise Level

The ICAO and FAR certification standards were mentioned in chapter three as ways of controlling aircraft noise at source. In principle both ICAO and FAR certifications serve the same purposes, however there are minor differences in the procedure for measuring the certification noise levels between the two organisations. The procedure described below is that of ICAO Annex 16.

For ICAO noise certification aircraft weighing over 5700 kg three measurement points are selected around the runway. The take-off measurement point is chosen at 6500m from start of take-off roll and along the extended runway centre-line. For approach conditions, a point which lies 120m under the flight path for a standard 3 degrees Instrument Landing System (ILS) glide slope and along the centre-line of the approach runway. The third point although not relevant to this study is a distance 450m on both sides from the runway centre line. Figure 5.2 shows the noise certification measurement points for ICAO.

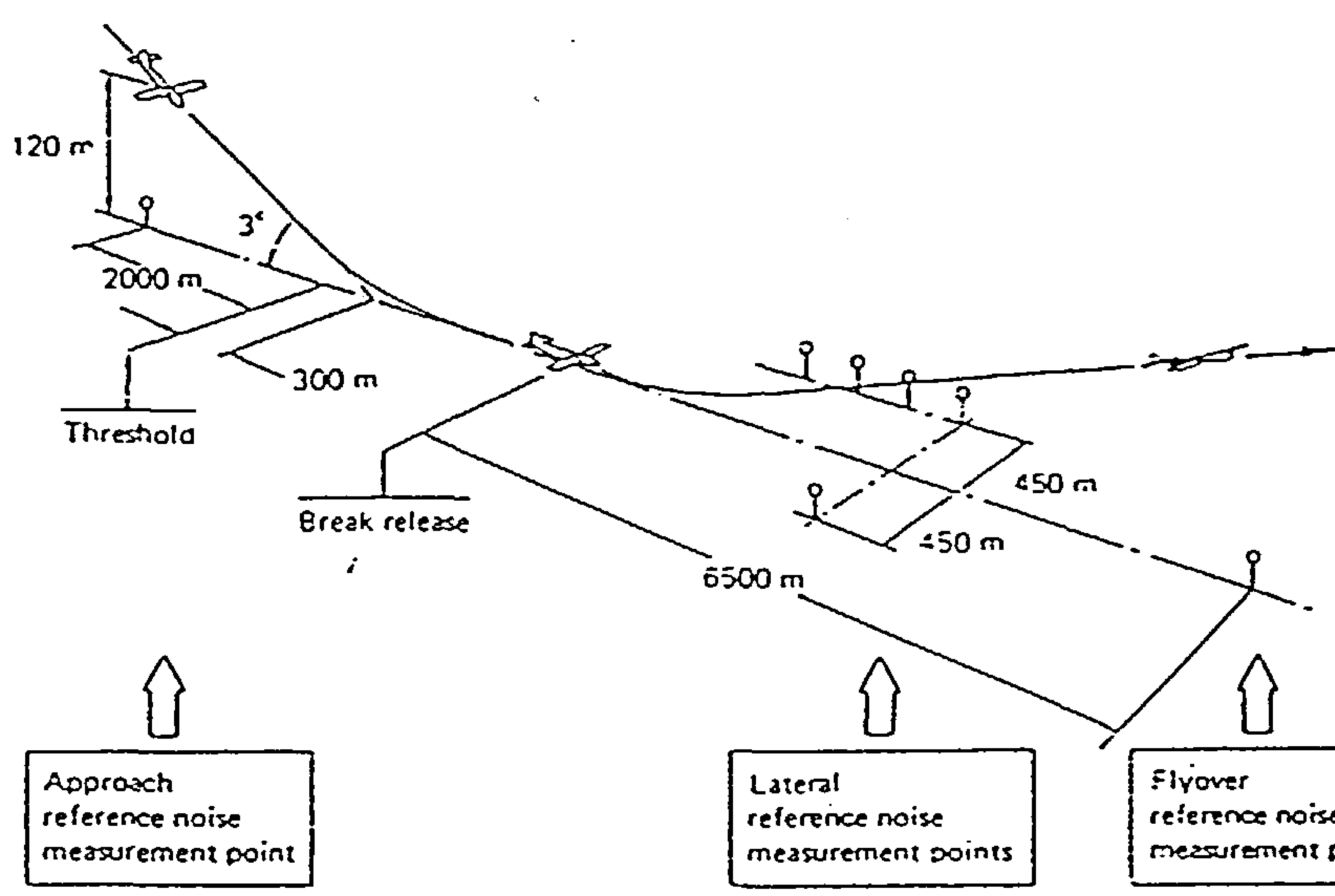


Fig 5.2 Noise Certification Measurement Points of ICAO
(Source: House, 1987)

The certification noise levels estimated are intended to provide a consistent basis for comparison of noise levels of major aircraft models operating out of commercial airports, rather than establishing absolute noise levels of individual aircraft. The noise levels of individual aircraft operating from different airports will differ due to variations in weight and operating procedures from those used during certification. For example, take-off noise level decreases substantially as aircraft take-off weight is reduced.

In this study Reference Noise Level is calculated using the maximum noise level equation, which is used for the calculation of average PNdB and thus the NNI. It is therefore necessary to explain how NNI is determined by calculating the average PNdB and similarly how average PNdB is determined by calculating the maximum noise level.

In calculating the RNL an assumption regarding the runway length is made. Together with the assumptions mentioned earlier for take-off and approach conditions, the reference noise level (at 500 ft) is calculated by working back from the NNI equation in the following way:

Noise Number Index is defined as

$$NNI = (\text{average PNdB}) + 15 \log N - 80$$

where N is the number of aircraft heard in the specified period and average peak noise level

$$PNdB = 10\log\frac{1}{N}\sum_{i=1}^{N}10^{L/10}$$

where L is the maximum noise level of each aircraft.

In order to calculate the NNI, the average PNdB of all the aircraft in the time period has to be known. The maximum noise level of each aircraft is required in order to calculate the average PNdB. In the NNI system, the maximum noise level at any point on the ground is obtained by modifying the reference noise level (RNL) to take account of the actual distance between the point and the flight path and the different attenuation which results.

Figure 5.3 illustrates a typical situation where, point P is laterally displaced from the flight track such that it is at a slant distance d to the flight path. The noise level at any point P is calculated using the formula:

$$L = L_o - k \log (d/500)$$

where

L maximum noise level

L_o is the reference noise level (RNL)

k the attenuation coefficient which varies with angle of elevation θ as shown in figure 5.4.

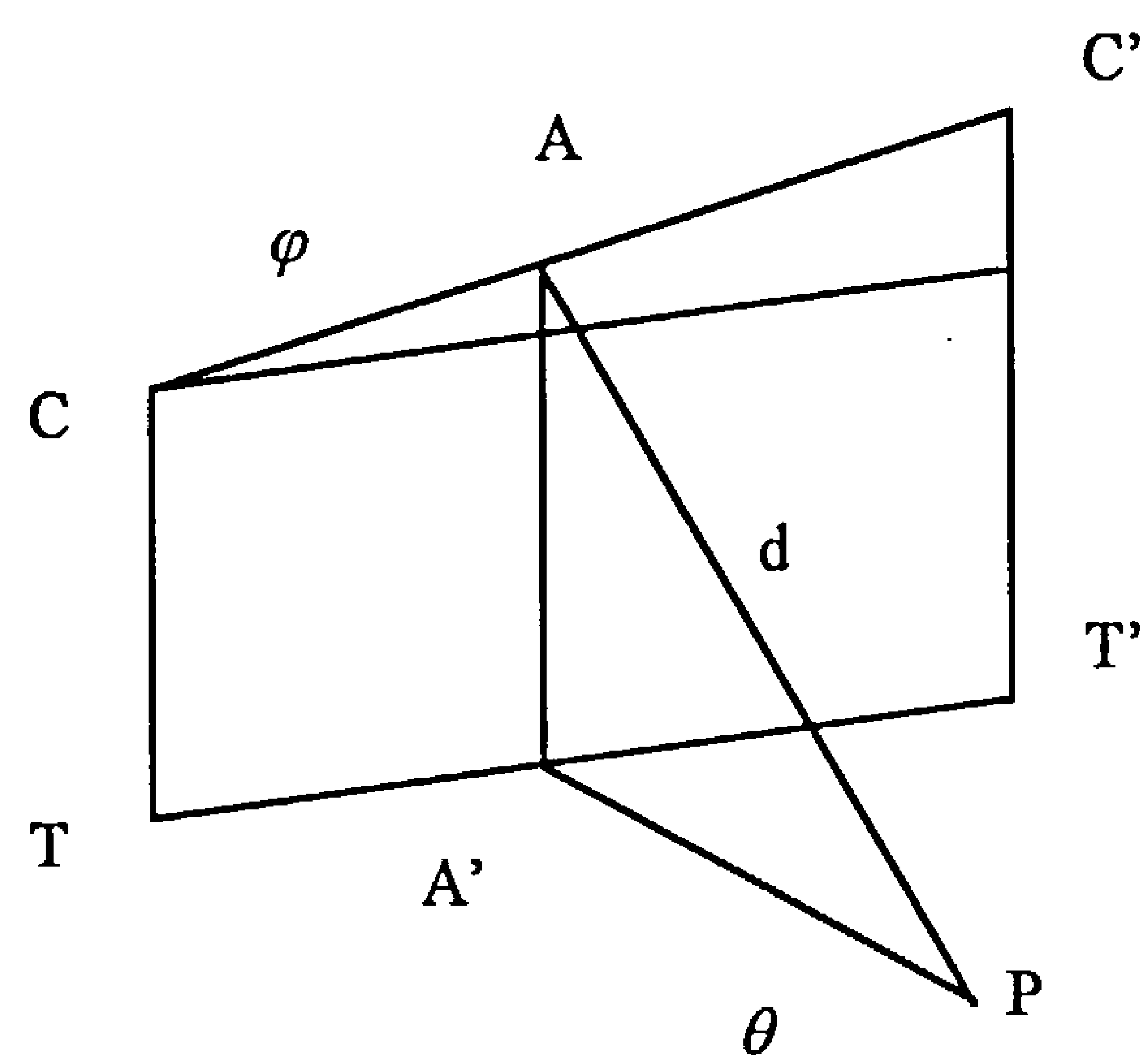


Fig 5.3 Representation of the Assumption for Maximum Noise Level at a point on the Ground. (Source: CAA, 1981)

A: Position of aircraft for which maximum noise is received on the ground at P

CC': Aircraft flight path

TT': Ground track of the aircraft

A': Projection of the aircraft on to the ground track

P: Position of the observer

φ: Angle of climb or descent of aircraft

θ Angle of elevation from observer P to aircraft

d: Slant range of aircraft

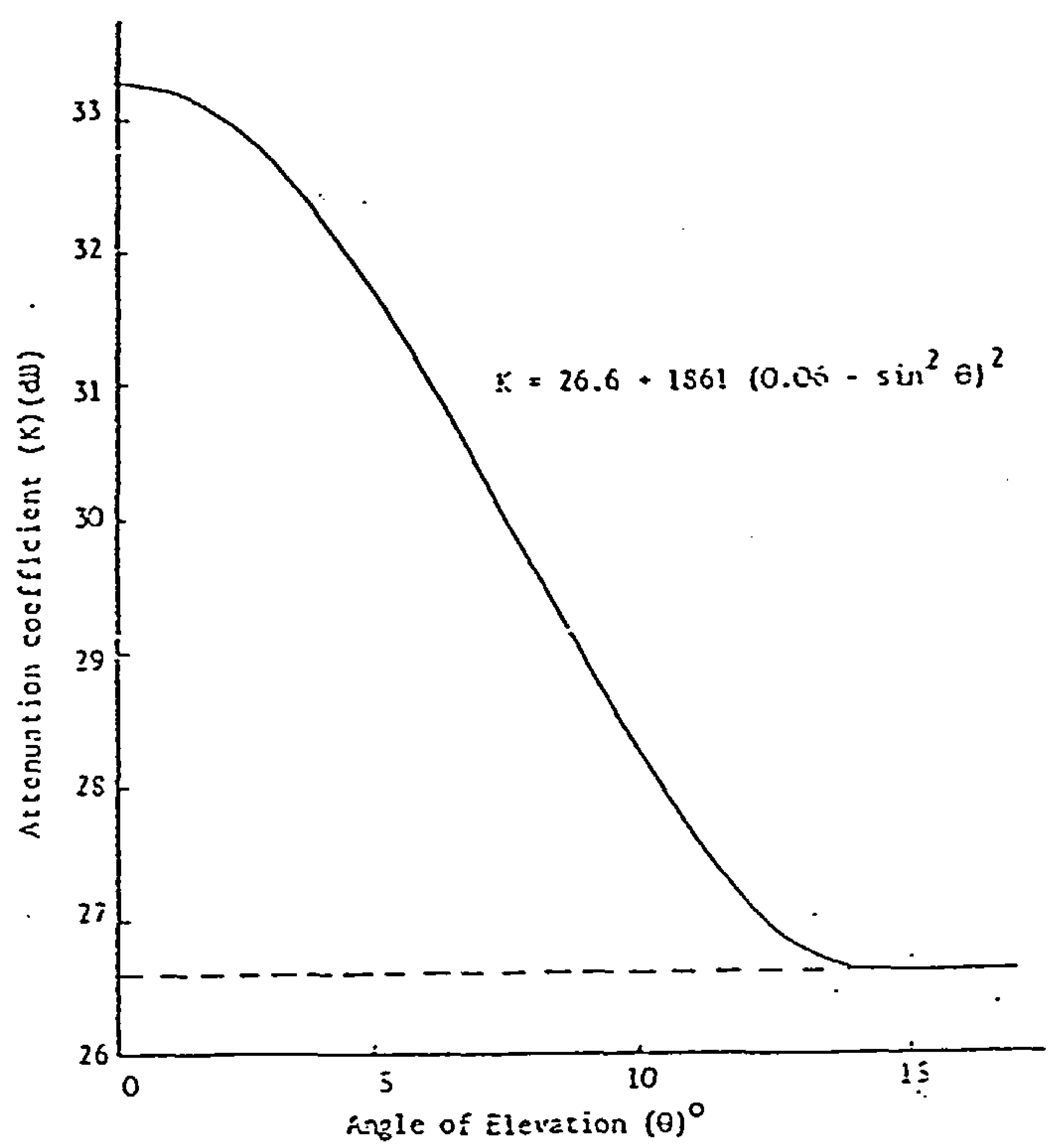


Fig 5.4 Allowance for Ground Attenuation in NNI predictions (Source: House, 1987)

Since the point of interest here is the reference noise level which is directly below the flight path, then angle of elevation is 90 degrees which makes the coefficient of attenuation 26.6. Figure 5.5 summarises the assumptions regarding the flight paths for take-off and the runway length used for calculating the reference noise levels of each aircraft.

5.3.2 Reference Noise Level for Take-off

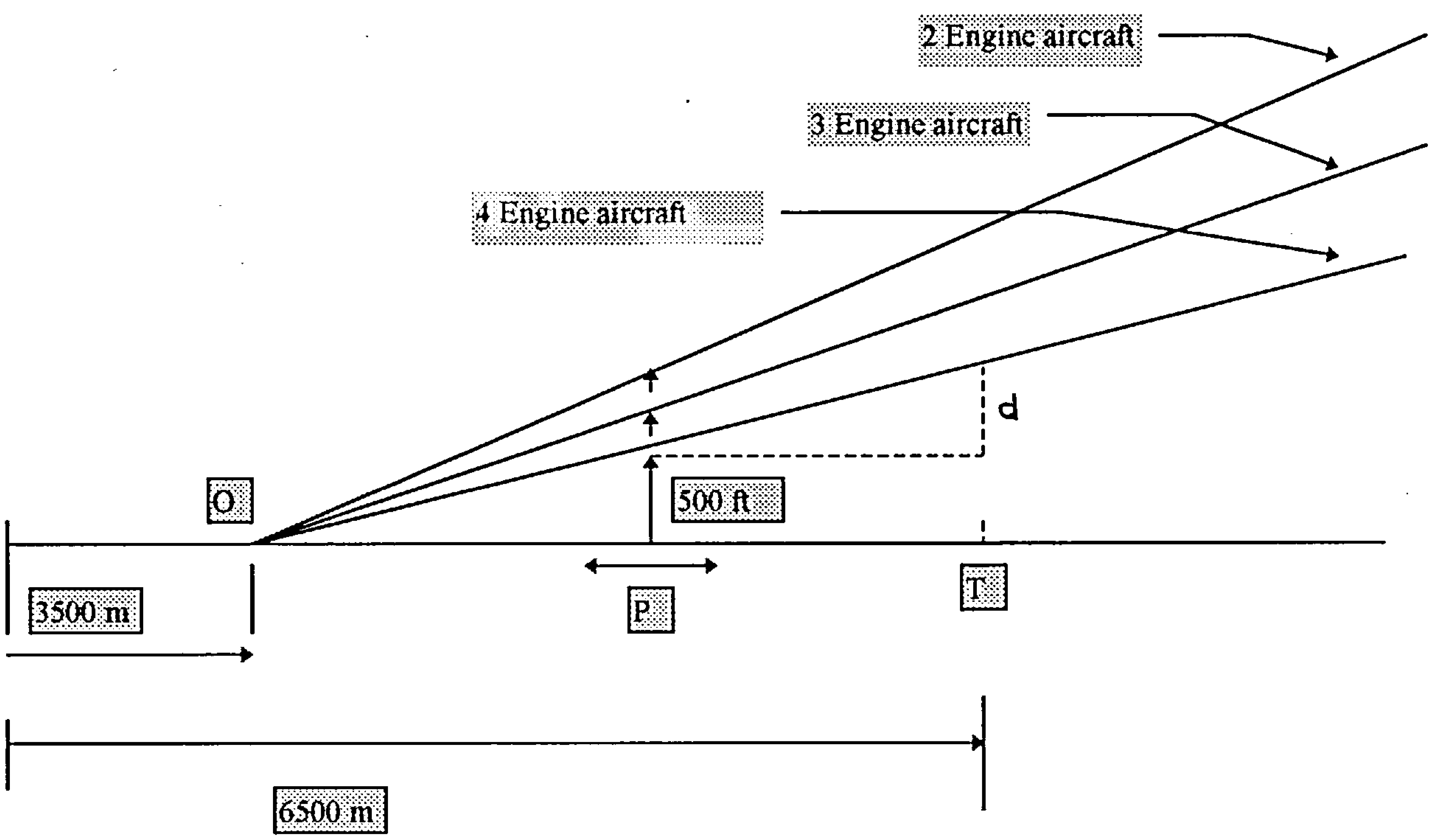


Fig 5.5 Flight Path Profile for Take-off

Location T is the distance 6500m from start of take-off roll which is used for measuring certification noise level by ICAO. All aircraft are assumed to take-off at O. Depending on which flight path is under consideration, the point P on the ground directly 500 ft below the flight path varies accordingly. For example for the four-engine aircraft taking-off at 7 degrees OP is 1.241 km, then from trigonometry the height (d) can be evaluated.

Hence with k = 26.6, knowing d and using certification noise level at T, the equation

$$L = L_0 - k \log (d/500)$$

can be re-arranged to give the reference noise level

$$L_o = L + k \log (d/500)$$

Using the above relationship the reference noise levels (RNL), have been extrapolated from certification noise levels at T.

5.3.3 Reference Noise Level for Approach

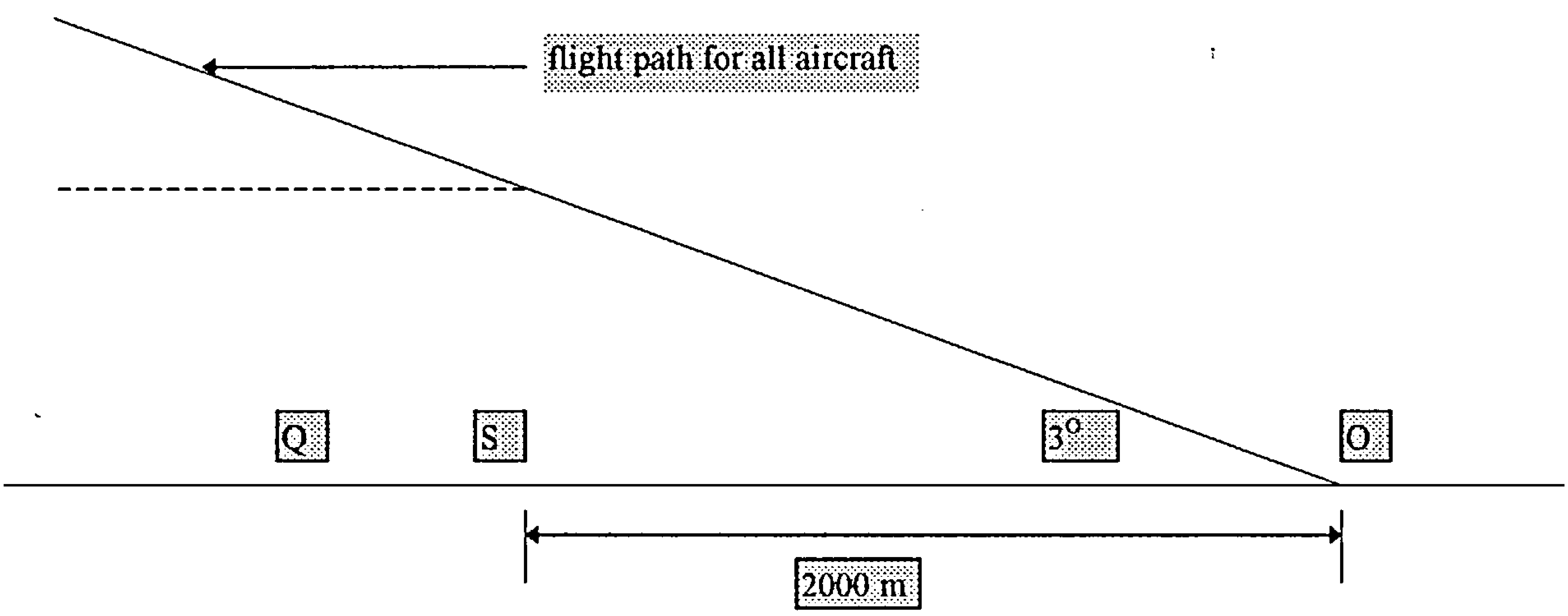


Fig 5.6 Flight Path Profile for Approach

Point S in figure 5.6 represents the certification noise level measurement point for approach by ICAO. Point Q is the reference noise level directly below the flight path. The actual reference noise level measured at airports varies as much as 10 dBA for any aircraft type both for take-off and approach conditions. The vertical height difference to the flight path between point S and Q is insignificant compared to the large discrepancy in measured reference noise levels. This reduces the significance of making adjustments from certification noise level to reference noise level for such a small height difference between the two points. Hence the certification noise level for approach were taken to be a good representation of the reference noise level for approach conditions. Some comparisons with aircraft types produced by House (1987) supports this argument.

Table 5.2 shows the certification noise level and the reference noise level (RNL) for both take-off and approach for aircraft operating at the airports chosen for this study.

Noise Levels in PNdB for			
Aircraft Type	Approach Certification	Take-off Certification	Take-off Reference
CONCORDE	122	125	129
B747	110	109	113
B707/720	118	117	121
ILYUSHIN 86	110	107	111
DC10	107	103	113
MD 11	105	103	113
L TRISTAR	104	99	109
TU 154	102	94	104
B727	104	101	111
BAe 146	99	89	102
B767	102	89	102
A310	102	89	102
A300	104	91	104
F 27	92	91	104
B757	99	84	97
TU 134	104	100	113
B737	105	100	113
BAe 1-11	105	100	113
DC9/MD 80	106	100	113
F 28	100	92	105
F 100	96	85	98
A320	94	85	98
HERALD	93	88	101
F 50	93	88	101
SAAB 340	94	78	91
EMB BAND	89	84	97
SHORTS	95	81	94
ATR 42	95	81	94
BAe 748	101	91	104
EMB BRASILIA	89	84	97
BAe ATP	96	91	104
BAe JET	89	78	91
DASH 7	97	72	85
DASH 8	93	72	85
L ELECTR	94	74	87
DC 8	105	98	111

Table 5.2 Reference Noise Level for Aircraft Operating at Airports

The reference noise level obtained using this procedure both for approach and take-off, is a lower estimate than that of real situations at airports. Primarily because the attenuation coefficient k is higher in real situations than that used in the equations. However, the reasons are many some of which are operating procedures, take-off weight and runway characteristics.

5.4 The Maximum Noise Level

To assess the change in NNI over two contour levels the calculation of NNI is required, which involves determining the average PNdB. The peak noise level has to be determined in order to calculate the average PNdB. From the established reference noise level, the maximum noise level of any aircraft type along the flight path can be extrapolated using the formula:

$$L = L_0 - k \log (d/500)$$

where

L maximum noise level

L_0 reference noise level (P for take-off and Q for approach)

k 26.6 with $\theta = 90$ degrees

and (d) can be evaluated using simple trigonometry.

The following sections demonstrate for Heathrow airport, the calculations of the noise charge for both take-off and approach. Data related to other airports regarding the noise landing charge is also presented. For all airports the procedures used are the same as that of Heathrow.

5.4.1 Maximum Noise Level for Take-off

Locations A, B and C shown in figure 5.7 are the boundaries of contour lines for 55, 45 and 35 NNI respectively, on a horizontal cross section of the contour maps obtained for the selected airports. Point P is 500 ft below the flight path, i.e. the point on the ground for reference noise level which varies according to the aircraft types and different angles of take-off for each of the airports.

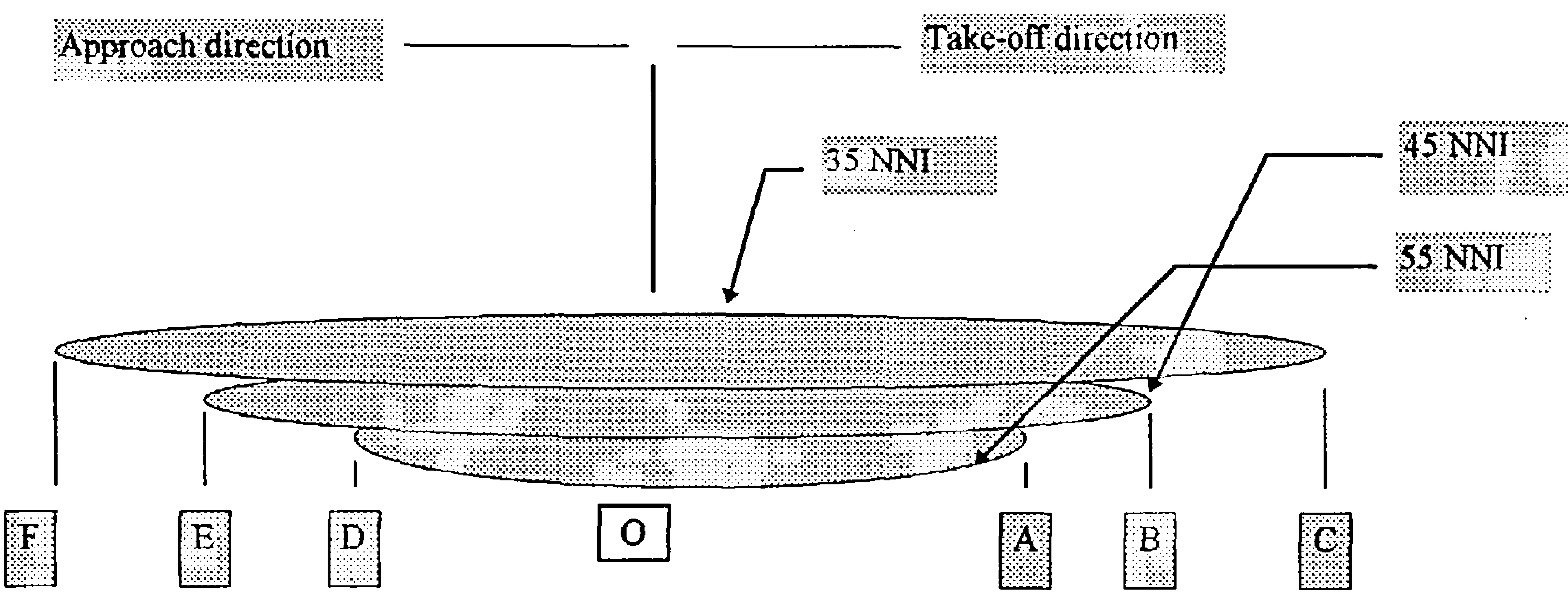


Figure 5.7 Location of Contour Levels on a Horizontal Cross Section

Table 5.3 shows the calculations for Heathrow for take-off, the reductions of noise level in PNdB for each group of aircraft, categorised by engine number. As shown by table 5.3 all four engine aircraft at location A, PNdB reduces by 14.88 from point P which is the location of the reference noise level. Similarly at location B for all two engine aircraft, PNdB reduces by 30.44. Using the same procedure for all the airports, the reduction of PNdB is calculated from reference noise level to the corresponding locations representing 55, 45 and 35 NNI.

Although the locations A, B and C represent the corresponding NNI values but their location on the ground below the flight path, varies according to traffic volumes and operating procedures of the associated airports. The values under the heading "Subtract from reference noise" in the final column of table 5.3, represents the factor klog(d/500) at the respective points under the flight paths. Hence the peak noise at the various points are simply the reference noise level (RNL) minus the klog(d/500) value.

(Reduction of PNdB with distance)					
Location Engine Type	OP (Km)	PA (Km)	d (ft)	d(A) (ft)	Subtract from RNL (PNdB)
A (4)	1.24	3.26	1313	1813	14.88
A (3)	0.86	3.64	2103	2603	19.06
A (2)	0.72	3.78	2638	3138	21.22
				d(B) (ft)	
B (4)	1.24	8.76	3528	4028	24.10
B (3)	0.86	9.14	5285	5785	28.28
B (2)	0.72	9.28	6474	6974	30.44
				d(C) (ft)	
C (4)	1.24	16.76	6751	7251	30.89
C (3)	0.86	17.14	9913	10413	35.07
C (2)	0.72	17.28	12052	12552	37.23

Table 5.3 Reduction of PNdB with distance at Heathrow

For all the airports the following symbols are used:

A (4) four-engine aircraft at A

B (3) three-engine aircraft at B

C (2) two-engine aircraft at C

d (A) distance from flight path(s) to point directly below on ground at A

d (B) distance from ------- at B

d (C) distance from ------- at C

Table 5.4 shows the maximum noise levels for each aircraft type at locations A, B and C. Table 5.5 shows the average PNdB and the respective NNI values as a result of an additional aircraft flyover at these positions. The reproduced values of NNI at A, B and C have been identified with the contour maps from the airport authorities, and observing the figures in the calculations of NNI (at A, B and C) for all the airports demonstrate a close resemblance of the accuracy of prediction.

Heathrow Airport –Take Off						
Aircraft Type	Annual Movement	Daily Movement (Day)	Reference Noise P	Maximum Noise at A	B	C
CONCORDE	1775	5	129	114.12	104.90	98.11
B747	42058	116	113	98.12	88.90	82.11
B707/720	775	2	121	106.12	96.90	90.11
ILYUSHIN 86	466	1	111	96.12	86.90	80.11
DC10	3107	8	113	93.94	84.72	77.93
MD 11	835	2	113	93.94	84.72	77.93
L TRISTAR	1107	3	109	89.94	80.72	73.93
TU 154	2025	5	104	84.94	75.72	68.93
B727	5571	14	111	91.94	82.72	75.93
BAe 146	1593	4	102	80.78	71.56	64.77
B767	30881	85	102	80.78	71.56	64.77
A310	20482	56	102	80.78	71.56	64.77
A300	6199	16	104	82.78	73.56	66.77
F 27	2731	7	104	82.78	73.56	66.77
B757	56297	155	97	75.78	66.56	59.77
TU 134	271	1	113	91.78	82.56	75.77
B737	114724	318	113	91.78	82.56	75.77
BAe 1-11	279	1	113	91.78	82.56	75.77
DC9/MD 80	50018	138	113	91.78	82.56	75.77
F 28	4102	11	105	83.78	74.56	67.77
F 100	947	3	98	76.78	67.56	60.77
A320	32400	89	98	76.78	67.56	60.77
HERALD	195	1	101	79.78	70.56	63.77
F 50	1269	4	101	79.78	70.56	63.77

Table 5.4 Maximum Noise Levels at Locations A, B and C

Heathrow Airport - Take off (Day Hours Calculations)								
Addition of Aircraft Type		Total Aircraft	Average PNdB at A	B	C	Noise Number Index at A	B	C
		1045	94.15	84.41	78.15	59.44	49.70	43.44
CONCORDE	1	1046	94.53	84.77	78.53	59.82	50.06	43.82
B747	1	1046	94.16	84.42	78.16	59.45	49.71	43.45
B707/720	1	1046	94.21	84.47	78.21	59.50	49.76	43.50
ILYUSHIN 86	1	1046	94.15	84.41	78.15	59.45	49.71	43.45
DC10	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
MD 11	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
L TRISTAR	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
TU 154	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
B727	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
BAe 146	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
B767	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
A310	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
A300	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
F 27	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
B757	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
TU 134	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
B737	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
BAe 1-11	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
DC9/MD 80	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
F 28	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
F 100	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
A320	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
HERALD	1	1046	94.15	84.41	78.15	59.44	49.70	43.44
F 50	1	1046	94.15	84.41	78.15	59.44	49.70	43.44

Table 5.5 Average PNdB and NNI at Locations A, B and C

For some of the airports, the calculated NNI values at the specified locations reflect near enough the actual values of NNI. This is due to the fact that for all the airports the annual movements were of 1992/93 while the corresponding contour maps were of 1988/89 in the case of Heathrow, Gatwick and Stansted airports. Whilst that of Manchester, Birmingham and Luton airports the contour maps were of 1991. It was not possible to obtain the contour maps to match the air traffic movements data for the same year, since contour maps are produced at a later time when the movement data have been collected. The inconsistency between the year of the data for the movements and the contour maps for the airports are likely to reduce the accuracy of the calculated NNI values.

However since the objective is to calculate the change in NNI between A, B and C (55-45 NNI, 45-35 NNI) for an aircraft flyover and as long as A, B and C represent near enough the 55, 45 and 35 NNI the requirements are satisfied. All the calculations shown for the airports in this section are for day hours, which is defined between 0600 - 1800 GMT hours. Referring to figure 5.7, the change in NNI between two contour levels are calculated by taking the average of the two contour levels. Thus between O to A, change in NNI is taken at A. Between A to B and B to C, the change in NNI is taken as the average of A and B and average of B and C.

Table 5.6 summarises the change in NNI over contour regions for a flyover of a particular type of aircraft. For all other airports the following procedure is used. From table 5.6 it can be seen that the change in NNI is consistent over the different contour zones for all the aircraft types. This is in agreement with the fact that change in NNI for an individual aircraft flyover is analogous to change in NNI for the aggregate of all aircraft irrespective of the values of the NNI i.e., NNI changes by the same amount for any aircraft flyover whether from 55 to 45 NNI or 45 to 35 NNI.

The values of change in NNIs for different aircraft types from table 5.6 indicates justification for grouping the aircraft by engine number. With the exception of TU 134, B737, BAe 1-11 and DC9/MD80 for all other aircraft in this group, NNI changes by the same amount. This is reflected by the similarity in reference noise levels for these aircraft types with the exception to the four mentioned above. For all aircraft with exception of Concorde, NNI changes by a very small amount over the contour zones. The noise cost for all aircraft would be substantially higher, should the change in NNI be similar in range to that of B707/720 as shown by table 5.9.

Aircraft Type	Change in NNI over contour zones at O-A	A-B	B-C
CONCORDE	0.386	0.375	0.375
B747	0.012	0.012	0.012
B707/720	0.065	0.063	0.063
ILYUSHIN 86	0.008	0.008	0.008
DC10	0.005	0.006	0.006
MD 11	0.005	0.006	0.006
L TRISTAR	0.003	0.003	0.003
TU 154	0.002	0.003	0.003
B727	0.004	0.004	0.004
BAe 146	0.002	0.002	0.002
B767	0.002	0.002	0.002
A310	0.002	0.002	0.002
A300	0.002	0.002	0.002
F 27	0.002	0.002	0.002
B757	0.002	0.002	0.002
TU 134	0.004	0.004	0.004
B737	0.004	0.004	0.004
BAe 1-11	0.004	0.004	0.004
DC9/MD 80	0.004	0.004	0.004
F 28	0.002	0.002	0.002
F 100	0.002	0.002	0.002
A320	0.002	0.002	0.002
HERALD	0.002	0.002	0.002
F 50	0.002	0.002	0.002

Table 5.6 Change in NNI over Contour Zones

5.5 Estimation of Number of Houses Effected by Aircraft Noise

For Heathrow, Gatwick and Stansted airports, scale drawings of the most recent contour maps available were used. In order to obtain a better estimation of the number of houses affected in the take-off and approach directions, the noise affected area inside the different levels of NNI were divided into square kilometres. The number of square kms in each boundaries of NNI were estimated for both take-off and approach. The population affected were divided in the same ratio as the square kilometres estimated and using 2.48 as the average family size in UK (Social Trends, 1993), the number of houses affected in each contour levels were calculated.

The population affected in each contour level were obtained from the published figures in Civil Aviation Policy (CAP 4). The population figures for Manchester airport were divided in the ratio 30:70. Since in the direction of take-off at Manchester airport, most of the area affected by aircraft noise happens to be rural land where the number of houses are less. For the approach side the noise affected area is the heavily built residential area of Stockport, therefore the number of houses affected are more.

For similar reasons at Birmingham airport, the number of houses towards the take-off direction are 80% of the total affected in the contour region. For Birmingham and Manchester airport the figures for number of houses affected by aircraft noise were obtained from the Local Council's environmental department.

It has usually been taken that 35 NNI represents the threshold of annoyance, in that the average person at this level is "a little annoyed" (Ollerhead, 1989). At 45 NNI the average person is "moderately annoyed" and at 55 NNI "very much annoyed". Contour levels of 35, 45 and 55 NNI are generally presented to depict areas of low, medium and high average annoyance in residential areas. Table 5.7 shows the number of houses affected between 35 NNI and 55 NNI for both take-off and approach directions for all the airports.

Number of Houses affected by Aircraft Noise			
Airport	Take-off	Approach	Total
Heathrow	206468	93129	299597
Gatwick	10391	7754	18145
Stansted	694	354	1048
Luton	4032	4032	8064
Birmingham	6154	1539	7693
Manchester	11335	26447	37782

Table 5.7 Number of Houses affected by Aircraft Noise

The value of houses in the regions of the various airports were obtained from the UK Department of Environment and the prices were of 1993 and are shown below.

Airport	Region	Price (£)
Heathrow	Gt. London	78,231
Gatwick Stansted Luton	South East	78,231
Birmingham	West Midlands	59,265
Manchester	North West	54,612

Table 5.8 House Price Values

5.6 The Noise Cost Model

The reasons for adopting a unit depreciation rate of house value with unit increase in noise level were discussed in the previous chapter. Knowing the value of each house, number of houses affected by aircraft noise from 35 NNI to 55 NNI, the change in NNI for a flyover of a particular type of aircraft and the depreciation rate, the social cost of noise is calculated by using the formula:

$$SC = V\,H\,N\,M$$

where

SC capitalised social cost of noise for 25 years per zone (£)

V average value of each house in the zone (£)

H number of houses affected by aircraft noise in the zone

N change in NNI during flyover of a particular aircraft

M depreciation rate (%) per NNI

In order to translate the social cost of noise calculated for 25 years into a cost per aircraft movement, using the value for social cost of noise and taking

Z the social cost per movement (£)

Y the annual social cost, at an interest rate of 10% and assuming the houses to have an estimated life of 25 years in the noise affected areas.

The net present value of 25 years for an interest rate of 10% is 9.0774 and 360 days per year,

$$Z = SC / (9.0774 \times 360)$$

Table 5.9 shows the calculations of noise cost for Heathrow airport. The values in the first two columns show the social cost of noise by aircraft type between the contour zones. O-A represents the values up to the 55 NNI and A-C represent the values for 55 to 35 NNI contour zones. The annual social cost (Y) is obtained by dividing the values by 360 (days per year) shown by the third and fourth columns. The social cost per movement (Z) is obtained by further dividing the annual social cost (Y) by 9.0774, which is the net present value of 25 years for an interest rate of 10%. Using exactly the same procedure as Heathrow airport, the noise cost for other airports are calculated for take-off.

Noise cost for Heathrow Airport - Take off					
	Social cost	betweeen	Annual	social cost	
Aircraft	O-A	A-C	O-A	A-C	Z
Type	(£)	(£)	(£)	(£)	(£)
CONCORDE	2522218	58149946	7006	161528	18567
B747	79382	1837047	221	5103	586
B707/720	426252	9825143	1184	27292	3137
ILYUSHIN 86	55114	1278291	153	3551	408
DC10	34402	861598	96	2393	274
MD 11	34402	861598	96	2393	274
L TRISTAR	21868	536810	61	1491	171
TU 154	16198	389869	45	1083	124
B727	26718	662477	74	1840	211
BAe 146	14620	348960	41	969	111
B767	14620	348960	41	969	111
A310	14620	348960	41	969	111
A300	15230	364786	42	1013	116
F 27	15230	364786	42	1013	116
B757	13906	330458	39	918	105
TU 134	26718	662477	74	1840	211
B737	26718	662477	74	1840	211
BAe 1-11	26718	662477	74	1840	211
DC9/MD 80	26718	662477	74	1840	211
F 28	15659	375890	43	1044	120
F 100	13991	332674	39	924	106
A320	13991	332674	39	924	106
HERALD	14405	343395	40	954	109
F 50	14405	343395	40	954	109

Table 5.9 Noise Cost at Heathrow for Take-off

5.6.1 Noise Cost for Approach

For approach the calculations are identical to that of take-off conditions. Locations D, E and F are selected in the same way as A, B and C have been identified for take-off (see fig 5.7). Location D, E and F represent the 55, 45 and 35 NNI respectively directly below the flight path for approach. Q is the point on the ground where reference noise level are taken for approach, thus OQ is a distance 2 Km. As an example D is the point representing 55 NNI, therefore distance QD is calculated from the contour map of the respected airport. "d" represents the vertical distance to the flight path above point Q and d(D) represents the vertical distance to the flight path above the location D. The values under the heading "Subtract from reference noise" in the final column in table 5.10 represents the factor klog(d/500) at the respective points under the flight paths. Hence the peak noise at the various points were simply the RNL minus the klog(d/500) value, which is analogous to the calculations of take-off.

Heathrow Airport - Approach (Reduction of PNdB with distance)					
Location	OQ (Km)	QD (Km)	d (ft)	d(D) (ft)	Subtract from RNL (PNdB)
D	2.0	2.60	447	791	5.30
		QE (Km)		d(E) (ft)	
E	2.0	9.40	1616	1960	15.78
		QF (Km)		D(F) (ft)	
F	2.0	15.00	2579	2923	20.40

Table 5.10 Reduction of PNdB with Distance at Heathrow for Approach

Tables 5.11 to 5.14 show the processes for calculating the noise cost for approach for Heathrow, which are derived in the same way to that of take-off conditions. Table 5.12 shows the calculations for average PNdB and NNI at locations D, E and F. The total number of aircraft operating are 1045 for a day. The average PNdB and NNI at the respective locations are calculated for the total number of aircraft operating, shown by the first line in table 5.12. The increase in average PNdB and therefore NNI at the locations due to an additional aircraft flyover by type is then calculated. The magnitude of the additional increase in NNI due to the flyover of an aircraft type depends on the total number of aircraft operating at that airport. The change in NNI over the contour zones due to the flyover of aircraft type are shown in table 5.13.

Table 5.15 summarises the total cost per movement by aircraft types for all airports. The total cost per movement due to noise only is obtained by adding the approach and take-off costs.

The social cost of aircraft noise at an airport is a function of reference noise level, total number of aircraft movements, the price and number of houses in the affected region and the depreciation rate of house values with increase in noise level. The social cost of noise is the highest for Heathrow for take-off and approach. This is due to the high number of houses in the noise affected areas and the value of houses are the highest compared to regions of other airports. The change in NNI for an aircraft flyover at Heathrow for both take-off and approach are low, since aircraft movements are the highest at this airport.

Heathrow Airport - Approach						
Aircraft Type	Annual Movement	Daily Movement (Day)	Reference Noise Q	Maximum Noise at D	E	F
CONCORDE	1775	5	122	116.70	106.22	101.60
B747	42058	116	110	104.70	94.22	89.60
B707/720	775	2	118	112.70	102.22	97.60
ILYUSHIN 86	466	1	110	104.70	94.22	89.60
DC10	3107	8	107	101.70	91.22	86.60
MD 11	835	2	105	99.70	89.22	84.60
L TRISTAR	1107	3	104	98.70	88.22	83.60
TU 154	2025	5	102	96.70	86.22	81.60
B727	5571	14	104	98.70	88.22	83.60
BAe 146	1593	4	99	93.70	83.22	78.60
B767	30881	85	102	96.70	86.22	81.60
A310	20482	56	102	96.70	86.22	81.60
A300	6199	16	104	98.70	88.22	83.60
F 27	2731	7	92	86.70	76.22	71.60
B757	56297	155	99	93.70	83.22	78.60
TU 134	271	1	104	98.70	88.22	83.60
B737	114724	318	105	99.70	89.22	84.60
BAe 1-11	279	1	105	99.70	89.22	84.60
DC9/MD 80	50018	138	106	100.70	90.22	85.60
F 28	4102	11	100	94.70	84.22	79.60
F 100	947	3	96	90.70	80.22	75.60
A320	32400	89	94	88.70	78.22	73.60
HERALD	195	1	93	87.70	77.22	72.60
F 50	1269	4	93	87.70	77.22	72.60

Table 5.11 Maximum Noise Levels at Locations D, E and F

Heathrow Airport - Approach (Day Hours Calculations)								
Addition of Aircraft Type		Total Aircraft	Average PNdB D	E	F	Noise Number Index D	E	F
		1045	100.01	90.01	85.01	65.30	55.30	50.30
CONCORDE	1	1046	100.17	90.17	85.17	65.46	55.46	50.46
B747	1	1046	100.02	90.02	85.02	65.31	55.31	50.31
B707/720	1	1046	100.07	90.07	85.07	65.37	55.37	50.37
ILYUSHIN 86	1	1046	100.02	90.02	85.02	65.31	55.31	50.31
DC10	1	1046	100.01	90.01	85.01	65.31	55.31	50.31
MD 11	1	1046	100.01	90.01	85.01	65.31	55.31	50.31
L TRISTAR	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
TU 154	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
B727	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
BAe 146	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
B767	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
A310	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
A300	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
F 27	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
B757	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
TU 134	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
B737	1	1046	100.01	90.01	85.01	65.31	55.31	50.31
BAe 1-11	1	1046	100.01	90.01	85.01	65.31	55.31	50.31
DC9/MD 80	1	1046	100.01	90.01	85.01	65.31	55.31	50.31
F 28	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
F 100	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
A320	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
HERALD	1	1046	100.01	90.01	85.01	65.30	55.30	50.30
F 50	1	1046	100.01	90.01	85.01	65.30	55.30	50.30

Table 5.12 Average PNdB at Locations D, E and F

Aircraft Type	Change in NNI over contour zones at: O-D	D-E	E-F
CONCORDE	0.164	0.164	0.164
B747	0.012	0.012	0.012
B707/720	0.067	0.067	0.067
ILYUSHIN 86	0.012	0.012	0.012
DC10	0.007	0.007	0.007
MD 11	0.005	0.005	0.005
L TRISTAR	0.005	0.005	0.005
TU 154	0.004	0.004	0.004
B727	0.005	0.005	0.005
BAe 146	0.003	0.003	0.003
B767	0.004	0.004	0.004
A310	0.004	0.004	0.004
A300	0.005	0.005	0.005
F 27	0.002	0.002	0.002
B757	0.003	0.003	0.003
TU 134	0.005	0.005	0.005
B737	0.005	0.005	0.005
BAe 1-11	0.005	0.005	0.005
DC9/MD 80	0.006	0.006	0.006
F 28	0.003	0.003	0.003
F 100	0.002	0.002	0.002
A320	0.002	0.002	0.002
HERALD	0.002	0.002	0.002
F 50	0.002	0.002	0.002

Table 5.13 Change in NNI over Contour Zones

Noise Cost for Heathrow Airport - Approach

Aircraft Type	Social Cost O-F (£)	Annual social Cost O-F (£)	Z (£)
CONCORDE	11945931	33183	3656
B747	908646	2524	278
B707/720	4899645	13610	1499
ILYUSHIN 86	908646	2524	278
DC10	531108	1475	163
MD 11	391003	1086	120
L TRISTAR	341722	949	105
TU 154	271468	754	83
B727	341722	949	105
BAe 146	211542	588	65
B767	271468	754	83
A310	271468	754	83
A300	341722	949	105
F 27	163336	454	50
B757	211542	588	65
TU 134	341722	949	105
B737	391003	1086	120
BAe 1-11	391003	1086	120
DC9/MD 80	453034	1258	139
F 28	227134	631	70
F 100	181504	504	56
A320	170365	473	52
HERALD	166448	462	51
F 50	166448	462	51

Table 5.14 Noise Cost at Heathrow for Approach

Noise Cost per Aircraft Movement at Airports (£)						
Aircraft	Heathrow	Gatwick	Stansted	Luton	Birmingham	Manchester
CONCORDE	22223					
B747	864	175	57			551
B707/720	4636	985	309			
ILYUSHIN 86	686					
DC10	437	79	24			
MD 11	394					
L TRISTAR	276	46				149
TU 154	207	32				
B727	316	54			453	160
BAe 146	176	25	3	150	136	84
B767	194	30	3	189	159	108
A310	194	30		189	159	108
A300	221	35		241		137
F 27	166	22	4	127	140	
B757	170	23	3	140	109	81
TU 134	316					
B737	331	57	2	427	643	196
BAe 1-11	331	57	15	427	643	196
DC9/MD 80	350	61	15	466	665	220
F 28	190	27			182	93
F 100	162	22	17			
A320	158	21		115	96	65
HERALD	160	21		118	111	
F 50	160		2		111	
EMB BAND		20	3	105		
SAAB 340		20	2	110	84	
SHORTS		21	2	114	89	
ATR 42		21	2			
BAe 748			4			
EMB BRASILIA			2			
BAe ATP				139	147	
L ELECTRA				110	82	
DASH 7					88	
DASH 8					80	
BAe JET					79	
DC 8						180

Table 5.15 Noise Cost per Aircraft Movement at Airports

Figure 5.8 shows how NNI changes with reference noise level (RNL) over the contour regions for take-off and figure 5.9 shows the same for approach for all the airports. For all the airports reference noise levels for aircraft start at about the same range, that is 85 to 90 PNdB. Reference noise levels and the change in NNI for individual aircraft are related with the total number of movements at that airport. The higher the number of movements, the less will be the change in NNI. Stansted, Luton and Birmingham have the lowest number of total movements compared to the other airports. Therefore as shown by the graphs for both take-off and approach the change in NNI at these airports are the highest.

Despite having a high value for change in NNI the social cost of noise is the lowest at Stansted. This is explained by the fact that at Stansted the number of houses affected by aircraft noise are extremely low compared to the other airports. The change in NNI at Gatwick is similar to that of Manchester, however the number of houses affected at Gatwick is almost half to that of Manchester. This reasons with why at Manchester the cost of noise is higher than at Gatwick.

For an average aircraft movement the social cost of noise at Birmingham, Manchester and Luton lie in the middle, in between the highest at Heathrow and the lowest at Gatwick and Stansted airports.

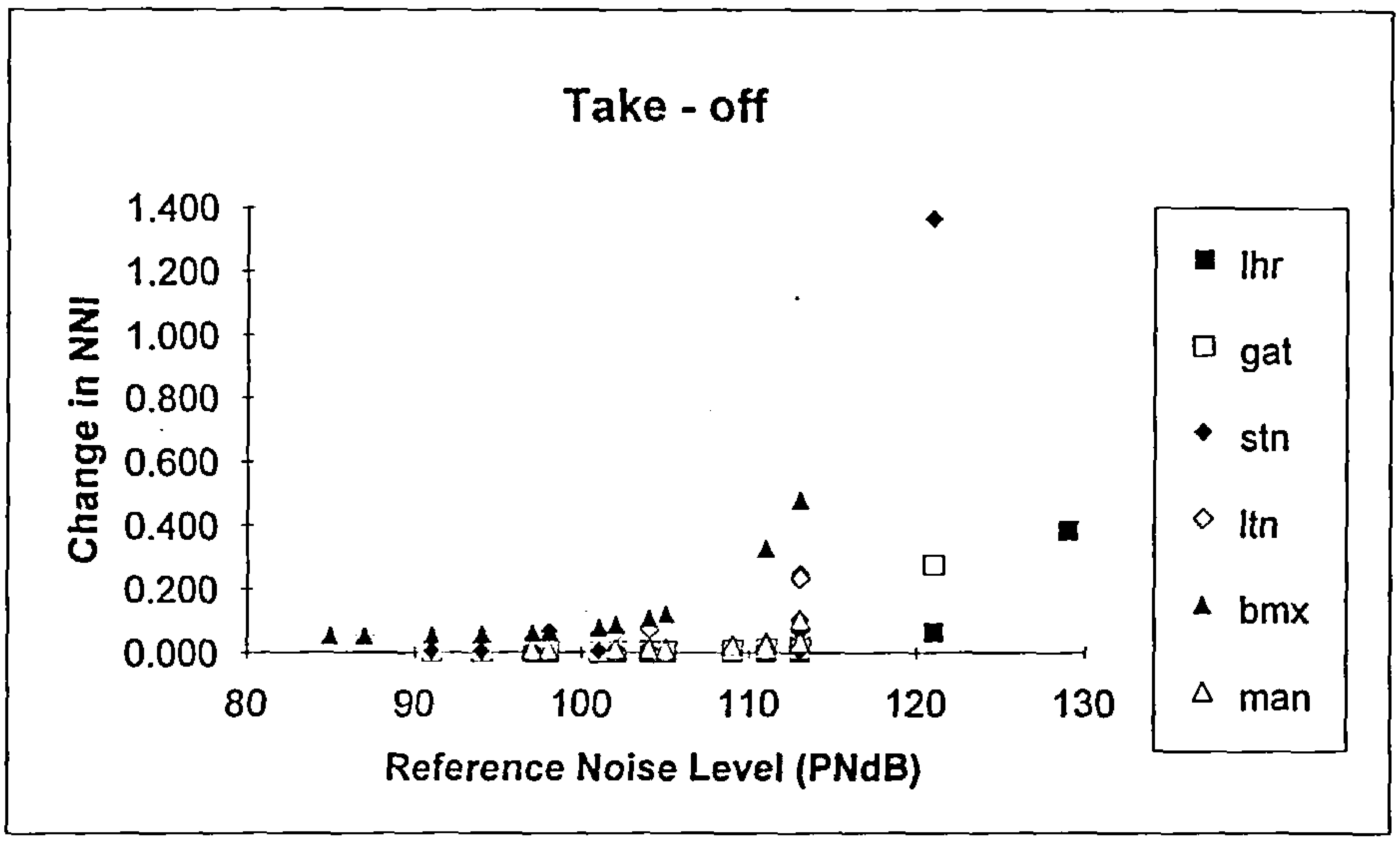


Fig 5.8 Change in NNI with Reference Noise Level for Take-off

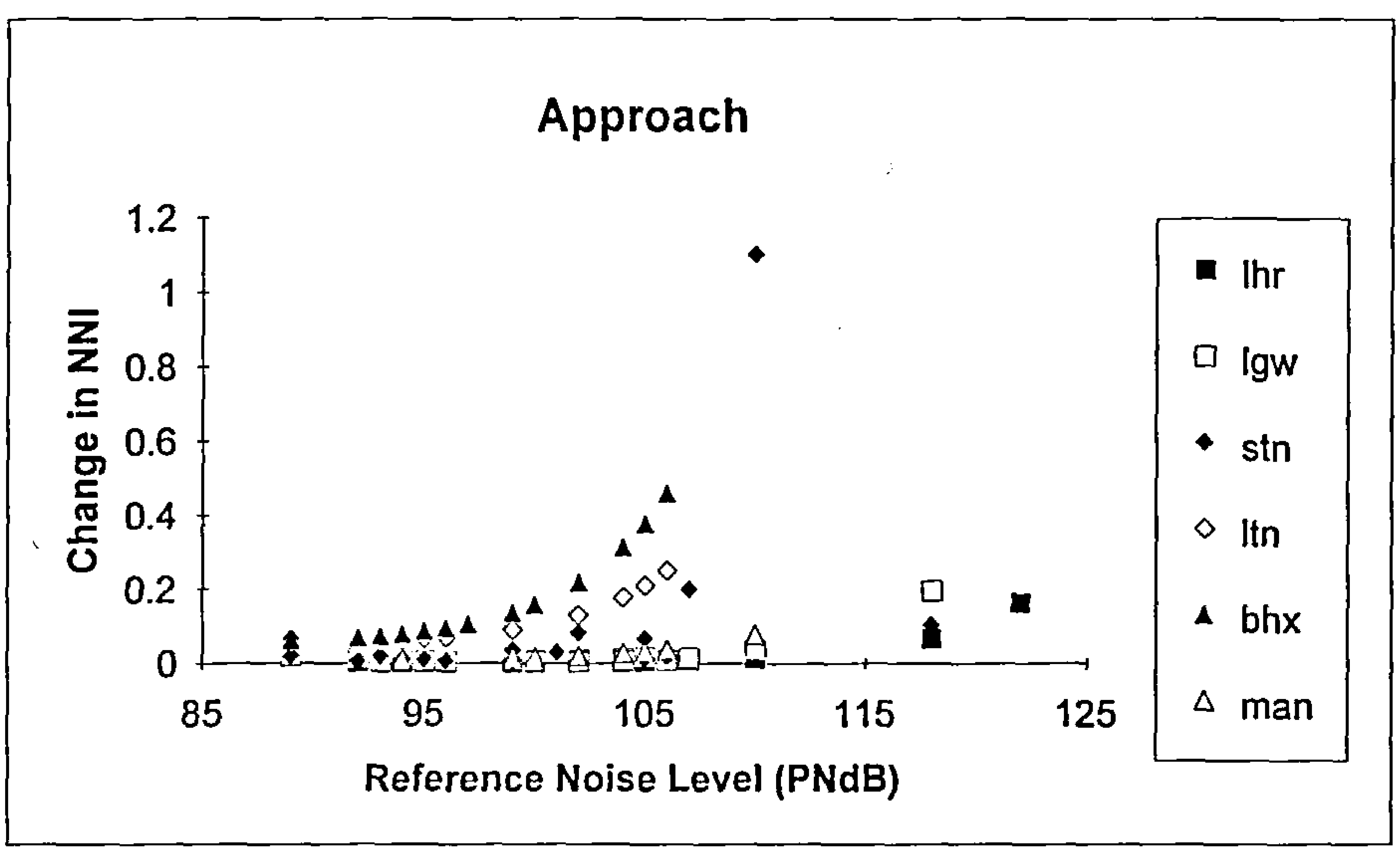


Fig 5.9 Change in NNI with Reference Noise Level for Approach

5.7 The Noise Landing Charge

The previous section has shown the noise cost per movement for aircraft types at the selected airports. This section examines the basis on which current landing charges are formed and to this the noise cost is added to develop the noise landing charge. Currently different airports make use of a number of factors such as weight of aircraft, size of aircraft, peak and off-peak times in order to distinguish the landing charge for different aircraft.

In this section the 1993/94 practices of landing charging are examined for the various airports. The noise cost is included to the airport landing charge to form the noise landing charge. Tables 5.16 and 5.17 show the noise landing charge per aircraft movement for the different airports. Prescribed method of evaluating the landing charges are taken into account based on schedule of charges provided by the airports concerned. For each of the airports the process for assessing the landing charges are shown below.

5.7.1 Heathrow

The conditions of the landing charge is based on the maximum total weight authorised and consists of a fixed charge. For all flight domestic and international,

	Peak £	Off-Peak £
Fixed wing aircraft not exceeding 16 metric tonnes	375.60	86.30
Fixed wing aircraft over 16 not exceeding 50 metric tonnes	417.30	174.30
Aircraft over 50 metric tonnes	417.30	303.65

Peak period - 0700 - 0959 UTC (GMT) and 1700 - 1859 UTC (GMT), 1 April to 31 October.

Off-Peak - All other times.

5.7.2 Gatwick

Charge is based on maximum total weight authorised and consists of two elements:

1 a fixed charge

2 a variable charge in the Off-Peak at a rate per tonne for aircraft with a maximum total weight authorised in excess of 50 metric tonnes

For all flights domestic and international,

	Peak £	Off-Peak £
Fixed wing aircraft not exceeding 16 metric tonnes	273.90	46.95
Fixed wing aircraft over 16 not exceeding 50 metric tonnes	304.35	59.15
Aircraft over 50 metric tonnes	304.35	59.15 plus 62p per metric tonne or part thereof in excess of 50 metric tonnes

Peak period - 0600 - 1059 UTC (GMT) and 1700 -1859 UTC (GMT), 1 April to 31 October

Off-Peak - All times 1 November to 31 March

5.7.3 Stansted

Charge is based on maximum total weight authorised and consists of two elements:

1. a fixed charge
2. a variable charge at a rate per tonne for aircraft with a maximum total weight authorised in excess of 50 metric tonnes

For all flights domestic and international,

	Peak £	Off-Peak £
Fixed wing aircraft not exceeding 16 metric tonnes	36.15	30.50
Fixed wing aircraft over 16 not exceeding 50 metric tonnes	67.80	54.25
Aircraft over 50 metric tonnes	97.15 plus 3.44	63.30 plus 1.64
	per metric tonne or part thereof in excess of 50 metric tonnes	

Peak period 1 May to 31 October
Off-Peak 1 November to 30 April

5.7.4 Luton

The landing fee is based on the registered seating capacity of aircraft. The charge per registered seat is £2.75.

5.7.5 Manchester

Propeller driven aircraft	£7.12 per tonne or part
Jet aircraft	£8.99 per tonne for the first 120 tonnes and £7.63 per tonne or part thereafter

5.7.6 Birmingham

Up to 2 tonnes	£6.30 per 1/2 tonne or part
Over 2 tonnes	£11.80 per tonne or part

Noise Landing Charge per Movement (£)								
Heathrow			**Gatwick**			**Stansted**		
Aircraft	**Peak**	**Off-Peak**	**Aircraft**	**Peak**	**Off-Peak**	**Aircraft**	**Peak**	**Off-Peak**
CONCORDE	22640	22526	B747	479.7	414.6	B747	1153.1	596.4
B747	1281	1168	B707/720	1289.2	1103.1	B707/720	733.9	528.6
B707/720	5054	4940						
ILYUSHIN 86	1103	990	DC10	383.2	266.0	DC10	831.7	426.1
			L TRISTAR	349.9	190.8			
DC10	854	740	B727	357.9	129.5	BAe 146	70.4	56.9
MD 11	811	697	A300	338.9	155.6	B767	368.2	193.9
L TRISTAR	693	579	B757	327.7	121.9	BAe 748	71.6	58.1
TU 154	624	511	BAe 146	329.7	78.6	F 27	72.1	58.6
B727	733	619	B767	333.9	137.1	B757	318.2	170.1
			A310	333.9	143.6	EMB BAND	38.8	33.1
BAe 146	593	350	TU 154	335.9	121.7	EMB BRASI	37.7	32.1
B767	611	498	F 27	326.3	75.2	B737	145.3	87.1
A310	611	498	EMB BAND	293.4	66.5	BAe 1-11	83.1	69.5
A300	638	524	B737	361.3	124.5	DC9/MD 8	174.7	108.3
F 27	583	340	BAe 1-11	361.3	110.2	F 100	84.3	70.8
B757	587	473	DC9/MD 8	365.7	131.7	F 50	69.8	56.2
TU 134	733	490	F 28	331.8	80.7	ATR 42	69.5	55.9
B737	748	634	F 100	326.6	75.4	SHORTS	38.0	32.4
BAe 1-11	748	505	A320	325.8	94.6	SAAB 340	38.0	32.4
DC9/MD 80	767	653	SAAB 340	294.4	67.4			
F 28	607	364	HERALD	325.5	74.4			
F 100	579	336	SHORTS	294.7	67.8			
A320	575	462	ATR 42	325.2	74.0			
HERALD	577	334						
F 50	577	334						

Table 5.16 Noise Landing Charge per Movement at Airports

Noise Landing Charge per Movement (£)						
Luton		Birmingham		Manchester		
Aircraft	L. Charge	Aircraft	L.Charge	Aircraft	Peak	Off - Peak
BAe 146	370.2	B727	1364.1	B747	3311.8	2249.7
B767	793.7					
A310	958.7	BAe 146	586.1	L TRISTAR	1753.5	1091.7
A300	1190.2	B767	1669.8	B727	854.1	545.4
BAe ATP	336.8	A310	1793.0			
F 27	248.0	BAe ATP	418.0	BAe 146	355.6	355.6
B757	797.5	F 27	381.4	B767	1247.7	746.5
B737	785.0	B757	1448.4	A310	1327.4	798.6
BAe 1-11	754.7	B737	1392.5	A300	1443.6	884.9
DC-9	782.5	BAe 1-11	1071.1	B757	1110.3	647.5
A320	606.8	DC9/MD 8	1468.6	DC 8	1520.5	949.8
HERALD	228.0	F 28	573.2	B737	767.0	512.7
SHORTS	196.3	A320	953.2	BAe 1-11	522.1	376.8
SAAB 340	211.3	HERALD	340.9	DC9/MD 8	832.1	559.7
L ELECTRA	384.6	SHORTS	226.7	F 28	329.2	329.2
EMB BAND	157.4	BAe JET	160.4	A320	717.9	427.4
		SAAB 340	230.3			
		F 50	345.7			
		DASH 7	321.5			
		DASH 8	256.3			
		L ELECTR	703.5			

Table 5.17 Noise Landing Charge per Movement at Airports

5.8 Night Time Landing Charge

When deriving the Noise Number Index, the Wilson Committee found that average PNdB + 15logN of about 80 coincided with approximately zero annoyance. In order to equate approximately zero annoyance with average PNdB + 15logN, (where N is the number of noise events) subtraction of 80 is required. As mentioned earlier the Committee found that in many areas around Heathrow, measurement of aircraft peak noise levels less than 80 PNdB proved difficult because the background noise was of a similar level during the passage of an aircraft. Therefore for daytime operations measurement was restricted to peak noise levels greater than 80 PNdB.

Ford (1987) argues that "in principle the NNI could be evaluated for night-time period with a more stringent criterion set." In the United States the Noise Exposure Forecast (NEF) is defined for day hours (0700 - 2200) as

$$\text{NEF} = \text{average EPNdB} + 10 \log N - 88$$

and for night-time (2200 - 0700) hours

$$\text{NEF} = \text{average EPNdB} + 10 \log N - 76$$

where,

EPNdB is the effective perceived noise decibels and

N the number of operations

The NEF system is adapted for night time noise measurement by applying a 10 dB penalty to any noise occurring during the night. The Composite Noise Rating (CNR) has a similar approach in that the weighting factor applied to penalise the number of night time flights, Nn by 10 dB as compared with the day time flights Nd.

$$CNR = PNL + 10 \log (Nn + 10\ Nd) - 12$$

where PNL is the Perceived Noise Level.

Adapting the Noise Number Index using the analogy to Noise Exposure Forecast and Composite Noise Rating, the NNI "cut off" value of 80 PNdB reduced to 70 then in principle the NNI for night time flights serves the same purpose as does NEF and CNR. Based on this concept, the night noise landing charge has been calculated for all the other airports and are shown in tables 5.18 and 5.19.

Since the criteria used for assessing the night charges are the same for all airports, then the charges rise by a similar proportion at most of the airports. As in the case of day time noise cost, charges at LHR is the highest and at Stansted the lowest. The implications of the night time charges for certain aircraft would be much more severe than the day time charges, particularly at airports such as Heathrow, Luton, Birmingham and Manchester. The charges at Gatwick and Stansted are similar to the day time charges. Primarily this is due to the fact that cumulative noise (in NNI) for aircraft movement at these two airports are low, therefore only those houses are affected by aircraft noise that are near the perimeter of the runway.

Noise Cost and Landing Charges for Night Time Movements (£)								
Heathrow			Gatwick			Stansted		
Aircraft	N. Cost	L. Charge	Aircraft	N. Cost	L. Charge	Aircraf	N. Cost	L. Charge
B747	4729	5032.5	B747	256	495.4	DC10	81	483.2
DC10	2147	2450.6	DC10	50	237.1	BAe 146	17	71.0
TU 154	780	1083.3	L TRISTAR	28	173.2	F 27	17	71.0
B727	1500	1804.0	B727	34	109.8	EMB BAN	12	42.9
B767	679	983.0	A300	19	140.3	EMB BRA	12	42.9
A310	679	983.0	B757	13	111.7	B737	58	143.1
A300	799	1102.3	BAe 146	14	73.3	BAe 1-1	58	111.8
F 27	590	764.6	B767	17	124.0	DC9/MD	58	150.5
B757	563	867.0	F 27	12	71.3	F 100	23	77.7
B737	1556	1859.2	B737	36	103.7	ATR 42	13	67.1
DC9/MD 8	1624	1927.3	BAe 1-11	36	95.3	SAAB 34	12	42.8
A320	520	823.2	DC9/MD 8	39	108.9			
			A320	11	84.7			
			SAAB 340	10	57.4			
			SHORTS	12	58.6			
			ATR 42	12	71.2			

Table 5.18 Night Landing Charges at Airports

Noise Cost and Landing Charges for Night Time Movements (£)								
Heathrow			Gatwick			Stansted		
Aircraft	N. Cost	L. Charge	Aircraft	N. Cost	L. Charge	Aircraf	N. Cost	L. Charge
B747	4729	5032.5	B747	256	495.4	DC10	81	483.2
DC10	2147	2450.6	DC10	50	237.1	BAe 146	17	71.0
TU 154	780	1083.3	L TRISTAR	28	173.2	F 27	17	71.0
B727	1500	1804.0	B727	34	109.8	EMB BAN	12	42.9
B767	679	983.0	A300	19	140.3	EMB BRA	12	42.9
A310	679	983.0	B757	13	111.7	B737	58	143.1
A300	799	1102.3	BAe 146	14	73.3	BAe 1-1	58	111.8
F 27	590	764.6	B767	17	124.0	DC9/MD	58	150.5
B757	563	867.0	F 27	12	71.3	F 100	23	77.7
B737	1556	1859.2	B737	36	103.7	ATR 42	13	67.1
DC9/MD 8	1624	1927.3	BAe 1-11	36	95.3	SAAB 34	12	42.8
A320	520	823.2	DC9/MD 8	39	108.9			
			A320	11	84.7			
			SAAB 340	10	57.4			
			SHORTS	12	58.6			
			ATR 42	12	71.2			

Table 5.19 Night Landing Charges at Airports

5.9 Summary

This chapter has explained the process of calculating the Noise Number Index. For approach and take-off conditions, the reference noise levels for each aircraft are calculated from the certification noise levels. Using the same equation as the reference noise level, the maximum noise level at locations A, B and C which represent the 55, 45 and 35 NNI have been calculated. Using the maximum noise level at A, B and C the calculated NNI values are reproduced.

For Heathrow airport for take-off conditions, the process of calculating the noise cost is explained. First the change in NNI as a result of flyover of an aircraft type is calculated. Knowing the house values in the regions, number of houses affected by aircraft noise and the depreciation rate of house values with increase in noise level taken as 1%, the social cost is calculated. Amongst other formulas available for calculating the social cost of aircraft noise, the formula used in this study has been identified to reflect best the monetary valuation and simplicity of use for developing the noise charge.

In a similar way the calculations for approach for Heathrow airport are presented. Using exactly the same process the social cost of noise at other airports are produced, which are shown in tables 5.15. The results show Heathrow airport to have the highest noise cost for aircraft movements. Primarily this is due to the large number of houses affected by aircraft noise and the house prices are the highest compared to the regions of other airports. The social cost of noise is the lowest at Gatwick and Stansted airports.

The noise landing charges shown by tables 5.16 and 5.17, takes account of the noise cost and the other factors such as maximum take-off weight (MTOW), size of aircraft, peak and off-peak times which are used for evaluating landing charges at airports. Tables 5.18 and 5.19 show the night noise landing charges based on the concept that, for night time flights noise levels are penalised by 10 dB as much as the day time flights.

In the next chapter assumptions regarding the implementation of the noise charges are discussed. The background literature associated with travel behaviour and the type of model to be used for airport choice are also described. The modelling results are shown in chapter seven.

AIRPORT CHOICE MODEL

6.1 Introduction

In the last chapter landing charges were estimated for six of the busiest airports in England based on the social cost of aircraft noise. This section is concerned with the development of an airport choice model, which allocates passengers to airports based on data on their origin and travel destination. This topic is divided into two chapters, this chapter discusses the assumptions, theoretical background and the methodology used to develop the airport choice model. Chapter seven illustrates the data required to construct the model and presents the results regarding passenger demand at airports.

The second major objective of this research is to investigate the implications of the noise related landing charge to passenger demand at the selected airports. In order to accurately predict how demand changes at airports or the existing use of airports, it is necessary to make a number of assumptions.

The first assumption is concerned with the extent to which airlines pass on the change in landing charge due to the cost of noise on to fare levels. A number of studies demonstrate that in the long term airlines do pass added costs to passengers. Pearce (1976), examined the effect on fares if one hundred percent of noise charge is passed on to passengers. The conclusion was that high noise charges would significantly affect passenger demand on short haul traffic. Bishop and Thompson (1992), investigating peak load pricing in aviation for the case of charter air fares, discovered that charter airlines normally pass on added costs to passengers.

In chapter one in the discussion of airlines' strategic response to noise management policies (Gillen, Levesque and Smith, 1990), it was identified that overall if it is possible to pass on costs to passengers then airlines will do so. Alternatively airlines may transfer services from other cheaper airports to avoid the extra cost. Therefore these findings support the assumption that airlines will pass on the extra costs to passengers. In this study it has been taken that one hundred percent of the noise cost is transferred to the passengers in the form of higher fare. The implications of this assumption are that all airlines do not consume internally any of the extra operating costs due to the noise landing charge. In reality due to the competitive nature of the air transport market depending on the financial circumstances of the airlines, they will pass on the costs to passengers by different amount.

The second assumption is that airlines do not change the aircraft type in order to avoid high landing charges or introduce economies of scale or size. This assumption is an important requirement in order to predict the implication of the noise landing charge to passenger demand at airports. Since the noise charge is developed based on the current aircraft type and movements, then it is reasonable to assume that aircraft types are kept the same in order to evaluate the initial implications.

The final assumption refers to the capacity of airports to sustain the change in demand particularly in the case of increases in demand. However this assumption is a consequence of the implication of the noise landing charge and it is the purpose of this thesis to address this issue.

6.2 Airport Choice Modelling

The objective in this section is to develop an airport choice model based on passengers behavioural choice characteristics. The most recent modelling of this type has been carried out by CAA (1993) for the UK, known as the passenger allocation model. This model is based on the concept that passengers will choose an airport which is most attractive from an aggregation of a number of factors. These factors will vary between passenger types, i.e. leisure or business, on the long haul or short haul routes, by scheduled or charter aircraft. Factors such as frequency will attract passengers to an airport whilst other factors such as, access costs will tend to deter passengers. The criticisms of the passenger allocation model is well illustrated by Caves (1992), however the fundamental issues such as passenger stratification, market segmentation or route characteristics and the type of general model used in this study are in agreement with other findings on this topic. These are discussed in detail in the following sections.

6.2.1 Behavioural Choice Modelling

The data and data sources with the results of the model developed for airport choice, which best reproduces the observed choices by passengers are presented in the next chapter. The arguments and the methodology leading to the model development is discussed in the rest of this chapter.

The general from of the model developed in this study is that of a methodology commonly used for airport choice modelling. In determining airport choice and in general travel behaviour, it has been established that increased accuracy in modelling is obtained through the use of disaggregate data compared to aggregated data (Robinson, 1950; Walmsley, 1979). Previous work by Ashford and Benchemam (1987), Caves (1993), Thompson and Caves (1992), CAA (1993) and the most recent work by Brookes, Caves and Pitfield (1994) all disaggregate the passengers by business and non business category. Ashford and Benchemam (1987), further divide the non-business passengers into international leisure and international inclusive tours.

Given the origin and destination data stratified by passenger categorisation produced and available from CAA, for this research passengers were stratified into three groups as:

Business
Leisure Inclusive Tour (IT) and
Leisure Other (OT).

These three groups of passengers were further divided by United Kingdom origin and foreign based. Hence a total of six passenger types are used for modelling in this study.

6.2.2 Market Segmentation

Analogous to the CAA, Civil Aviation Policy 570 (1990) "Traffic Distribution Policy and Airport and Airspace Capacity" and the RUCATSE Report (1993), the models developed in this research are for three market types. Short haul, long haul and charter markets are identified to be served by the modelling process.

The full justification for developing models for these three market segments are given by CAA, CAP 570 (1990). With respect to this research, it is appropriate to develop models for different markets since in travel behaviour it has been established that passengers are affected in different ways by different factors depending on their socio-economic characteristics. Six passenger types were earlier described, therefore travelling to three different markets produce a total of eighteen models. Therefore in this study as illustrated by the next chapter, using the same general form of the model eighteen results are produced.

6.2.3 Model Specification

The model used in this research is of the logit type with utility that includes access time, frequency of airline services and fare. The general form of the model expressing the choice probabilities by individual passengers is:

$$P_{gk} = e^{V_{gk}} / \sum_{j=1}^{G} e^{V_{jk}}$$

where

P_{gk} = probability that alternative g will be chosen by individual k and
$V_{gk} = \beta_1 X_{1g}+......\beta_n X_{ng}$ = representing function of the utility of alternative g for individual k

β_0, β_1 ....β_n = parameters to be estimated and

X_{1g}, X_{2g}, ...X_{ng} = explanatory variables

Most of the airport choice modelling work make use of the multinomial logit model. This process of modelling has been adopted in this study, since this is a tested approach. The recent work by CAA for the RUCATSE Report by Brooke, Caves and Pitfield (1994) also make use of this methodology. The fundamental difference between CAA's RUCATSE Report approach and the modelling in this research is that in CAA's work, attraction factors are predetermined for different markets. Whilst in this research only three independent variables are used which are thought to be the most important parameters in airport choice, (Ashford and Benchemam, 1987; Harvey, 1987 and Brooke et al, 1994).

The number of possible variables entering the model as determinants of passengers' choice of airport are vast (Brooke et al, 1994). However for reasons discussed by Brooke et al (1994) previous attempts to model airport choice (Benchemam, 1986; Cogin, 1988; Ndoh et al, 1990) have used access time, flight frequency and fare and have obtained results with the necessary degree of accuracy. Initially for this study the model development is based on these three independent variables and the utility function of the model is written in the form

$$V_{gk} = \beta_1.(at)_g + \beta_2.(fq)_g + \beta_3.(fa)_g$$

where

at = Access time to airports (min)

fq = Frequency per week (fq/wk)

fa = air fare (£)

$\beta_1, \beta_2, \beta_3$ are coefficients to be estimated in the calibration

The research carried out to develop the models in this study involved detailed analysis based on regression. Data collected on origin and destination surveys by CAA for various airports, normally divide the UK into a number of regions and more specific data is provided for Greater London area and for other areas in the South East. A more detailed analysis is carried out in this study possibly for the first time, for the Greater London and South East area for different passenger types. The objective is to determine whether differences in access cost or ratio of access cost better explain the observed choice pattern amongst different passenger types and to see if there are consistencies between the other regions passengers' choice of airport to that of passengers from the Greater London area.

6.3 Summary

In order to accurately predict the implication on passenger demand at airports, two assumptions have been made in this chapter regarding the application of the noise landing charge. First it is assumed that airlines pass on the full cost of noise to passengers and secondly it assumes airlines do not change aircraft type in order to avoid the high noise landing charges.

Previous airport choice modelling work has shown that disaggregation of passengers produces useful results. Since data is available already in disaggregated form by CAA's origin destination surveys, this thesis develops models for different passenger types. To further accurately evaluate the implications of the noise cost on passengers, it is identified that modelling should be carried out for different market types. This is analogous to CAAs' 1993 and 1990 modelling where passengers are taken to be affected differently depending on market characteristics.

Thus models are developed for three passenger types business, leisure inclusive tours, leisure other, UK and foreign based and for short haul, charter and long haul markets. In total eighteen results are produced using the same general form of the model. The model to be used is of the logit type, with utility that includes access cost, frequency and fares. Research on airport choice modelling has been heavily dependent on the use of logit model, Ashford and Benchemam (1987), Thompson and Caves (1992) and Brooke et al (1994).

Therefore in this study it is identified that the general form of the logit model is to be used with access time, frequency and fare as the explanatory variables. These three variables are recognised to be the most important in passengers' choice of airports. The next chapter presents the data and discusses the modelling results.

MODELLING PASSENGER ALLOCATION TO AIRPORTS

7.1 Introduction

This chapter presents the data, data sources and the results of the models developed. The general background of model formation and the analysis for each market types are discussed. The modelling for short haul, charter and long haul markets are described in that order. The detailed analysis regarding inner and outer London areas for both international scheduled and charter passengers are described towards the end of the chapter. In the previous chapter three independent variables access cost, frequency and fare were identified to be the most important factors to determine airport choice behaviour. Therefore modelling is based on a combination of these three explanatory variables. The equation combines access time, frequency and fare in the form,

$$\ln (P_1/P_2) = \beta_1.(at) + \beta_2.(fq) + \beta_3.(fa)$$

where

P_1	= probability of choosing airport 1
P_2	= probability of choosing airport 2
at	= access time difference or ratio
fq	= frequency difference, logarithmic difference or ratio
fa	= fare or weighted fare difference
β_1, β_2, β_3	= coefficients to be determined

Additionally another variable (β_0) known as a "dummy variable" has been incorporated where necessary to the utility function. The use of dummy variables arises in situations where the independent variables do not provide a full explanation to the utility function. For example in CAA's RUCATSE modelling, airport specific constants are used that captures the utility (or disutility) associated with airports that are not otherwise accounted for. CAA have used factors such as passengers' conception of an airport, ease of parking and choice of airline amongst others.

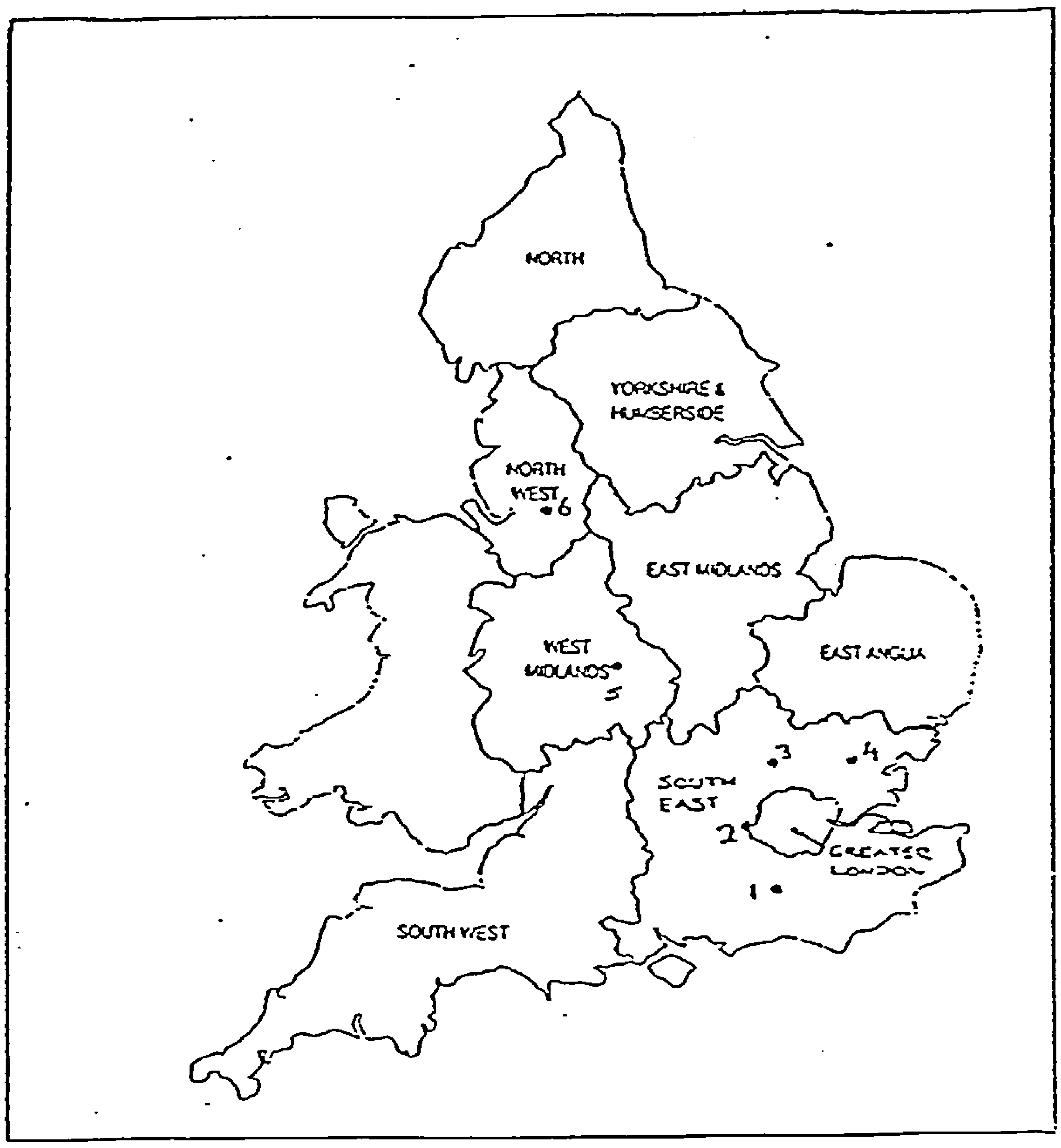
Using the basic form of the above equation a total of twelve equations are produced. With two options in the access time parameter i.e., the difference or ratio in access times between regions to airports. Three options in frequency either the difference, ratio or the logarithmic difference between airports. Two options in the fare parameter, either the weighted difference or the difference in fares between airports. In total twelve equations are produced for each of the passenger types for the short haul, charter and the long haul markets.

The objective is to determine by regression analysis for each passenger type for the specific market, the best equation which reproduces the observed choice. One of the major criticism of the CAA model (1990) outlined by Caves (1992), is that CAA for the short haul international scheduled model only take the ratio of frequency to be important and argues it to be restrictive in its predictive capability. Caves also point out that Brooke et al (1991) demonstrated considerable differences in the predictive capability of models using absolute frequency, frequency differences and frequency ratio. In this research combinations involving the difference, logarithmic difference and the ratio of frequencies are examined for each of the markets.

Detailed analysis of model development for the short haul market for UK business passengers is described in the following sections. Exactly the same process is used for foreign business, UK and foreign leisure IT and leisure OT passenger types in the short haul model and the passenger types for the charter model. However for the long haul model the process is described on its own basis since the data is limited for this particular market.

7.2 Short Haul Model

As mentioned earlier passengers are categorised into six groups for this study. UK and foreign business, leisure inclusive tour (IT) and other leisure (OT) passengers. Figure 7.1 shows the regions and airports used in this study and table 7.1 shows the total passengers travelling on international scheduled services from the airports. Passenger origin-destination data were obtained from the CAA CAP 610, which is the most recent survey (1991) carried out for the London area airports (Gatwick LGW, Heathrow LHR, Luton LTN and Stansted STN).



1 LGW
2 LHR
3 LTN
4 STN
5 BHX
6 MAN

Fig 7.1 Regions and Airports in the Study (Source: Regional Trends 28 HMSO, 1993)

Total International Scheduled Passengers

Orig/dest Regions	LGW	LHR	LTN	STN	BHX	MAN
EA	238800	612400	21339	177300	3072	2106
EM	206300	574600	27537	27896	211574	66326
GL	3877600	13746000	106958	244628	2856	837
N	61301	130201	861	2374	2858	95219
NW	102400	233600	1186	2796	14802	1608281
SE	3200400	10287900	156865	262391	31924	12190
SW	401800	1432000	4666	5257	40193	5696
WM	259200	609000	12824	8395	874329	122176
Y	158900	397900	689	3956	26100	446589
TOTAL	8506701	28023601	332925	734993	1207708	2359420

Table 7.1

Passenger data by origin-destination for Manchester (MAN) and Birmingham (BHX) airports were not available for 1991. In order to match the passenger data with other airports for the same year, the percentage of passengers by type and from regions were obtained from CAP 560 (1987), whilst the total passengers on international scheduled routes were obtained from CAP 604 (annual statement of movements, 1991). The total number of passengers were divided by the ratio of percentage difference from each of the regions. Therefore the total number of passengers were of the same year for all the airports, although a small degree of inaccuracy in the percentage of passengers from the different regions may exist for MAN and BHX, since reliance is based on extrapolation.

7.2.1 Route Selection

Six routes are chosen to represent the short haul market. Amsterdam (AMS), Brussels (BRU), Dublin (DUB), Frankfurt (FRA), Geneva (GVA) and Paris (CDG) are modelled. The same routes are used by the CAA 1990 and 1993 models, with the exception to Geneva instead Zurich route is used. For this study Zurich is taken for Manchester and Birmingham, since for the year modelled data on the Geneva route were not available. These routes represent some of the busiest routes for the short haul scheduled market and as outlined by CAA (1990), this accounts for forty percent of the traffic on the short haul scheduled market.

7.2.2 Access Cost

Previous studies by Ashford and Benchemam (1987), Thompson and Caves (1992) and Brooke et al (1994) all have used (for reasons which are justified) the Autoroute program to calculate the travel times. For this study it is appropriate that travel cost be calculated based on similar characteristics as that of the previous modelling works on this subject. It is acknowledged by Brooke et al (1994) that access times would vary by time of day, but as there exists no information on the times at which individuals travelled therefore it was not possible in their findings to take this into account. However in this study road conditions which affect travelling times, are taken into account by taking the average of the peak (rush hour road speeds) and off-peak (normal speeds) travel times.

Evans (1993) calculated in detail the peak and off-peak travel times for normal speeds for a number of UK airports from centroids of regions (used by CAA origin-destination data surveys). The average of the peak and off-peak travel times in minutes for this study are produced from Evans (1993) and are shown in table 7.2. The same access times are used for the charter and long haul modelling.

Average Travel Times from Regions to Airports (min)

Regions	LGW	LHR	LTN	STN	BHX	MAN
EA	209	172	113	73	168	239
EM	207	151	96	125	55	96
GL	102	50	72	84	137	219
N	347	291	236	256	192	157
NW	268	211	265	229	107	33
SE	65	55	108	127	158	243
SW	189	142	181	231	114	180
WM	191	134	97	153	29	67
Y	259	203	148	168	104	64

Table 7.2

7.2.3 Frequency and Fares

For the six routes taken to represent short haul scheduled market from the London airports, frequency and fare were obtained from ABC World Airways Guide for 1993. Initially frequency of March and July are taken to represent the busiest and quiet months of travel and average of the two months are taken for each of the routes. For BHX and MAN frequency from ICAO (1991) were used to match the passenger figures used from CAP 604 (1991). For each of the airports the average frequency per week of the six routes are taken shown by table 7.2.1.

One way economy "Y" fare are used and the average over the six routes are taken to represent the short haul market. The same values of access times, frequency and fare are maintained for all passenger types for the short haul model. Passengers either on business or non-business category receive discounts on fares based on travel characteristics, thus it is appropriate to use the published economy "Y" fares by the ABC Guide. Ashford and Benchemam (1987) and Brooke et al (1994) have used fare data in the same context as in this research.

	Fq	**Fares (£)**
LGW	51	167
LHR	197	167
LTN	10	127
STN	31	167
BHX	19	185
MAN	22	199

Table 7.2.1

7.2.4 Analysis Results for Regional and all Airports

The detailed discussion of the process of obtaining results for UK business passengers for the short haul model is described in this section. An exactly similar process is used in order to obtain results for the other passenger types. Having obtained data on access times from each regions to airports, the frequencies and the fares from each of the airports for routes on the short haul market, the following variables are produced.

i) Differences and ratios of access times between airports from various regions
ii) Differences, logarithmic differences and ratios of frequencies between airports
iii) Differences and weighted differences in fares between airports

The above variables combine to form in total twelve equations using the general form of the equation shown earlier in section 7.1. Regression analysis is carried out in order to determine which combination of variables reproduce best the observed choice behaviour. Regression analysis is carried out for region by region independently and then the aggregate of all regions. Theoretically a pattern should exist between individual regions' regression results and the results of the aggregate regions. The results of the twelve equations regressed by region and the aggregate regions for UK business passengers are shown in tables in sections 7.3 and 7.4. Tables in section 7.3 show all combinations of differences in access time equations whilst tables in section 7.4 shows all combination of access ratio equations.

To interpret the results reference has to be made to previous work in airport choice modelling. Ashford and Benchemam (1987), Harvey (1987), Thompson and Caves (1992) and Brooke et al (1994) all have used prior assumptions for the sign of coefficients for the explanatory variables. For the business passengers, access time and frequency are expected to be negative and positive respectively. For non business passengers, access time and fare are expected to be negative, as a decrease in their value would improve the level of utility or service to the passengers. Some cases such as Harvey (1987) have ignored the significance of the fare coefficient for the business passengers (air fare was not introduced in the model and its effect not determined). The fare coefficient for business passengers was dropped from the modelling by Ashford and Benchemam (1987), since it did not produce an expected negative sign. In this study fare coefficients are used in the modelling for business passengers.

Examination of the results from the tables in section 7.3 and 7.4 shows that *equation 6* from the differences in access times equations and the ratio of access times equations are the best in their group. The criteria used to assess this are the prior expectations of signs of coefficients, the t-statistics at the 95% confidence level associated with each of the coefficient estimates and the coefficient of determination r^2. As mentioned earlier, for the business passengers access time and frequency are expected to be negative and positive respectively. For the leisure passengers access time and fare coefficients are expected to be negative whilst frequency is expected to be positive.

Using these criteria *equation 6* from the *access time differences* yields better results than the ratio of access time equation 6 (see pages 133 and 134). However for the next stage of the assessment criteria, the best equation found is used to reproduce the predicted passenger demand at airports. It is at this stage found that for all passenger types, the differences in access time equations are better than the ratio of access time equations. Hence the best equation from the differences of access time equations are used to predict the actual observed choice of airports by passengers.

Investigating the observed and predicted results for business passengers at UK for the short haul model, with independent variables of differences in access time (dat), logarithmic differences in frequencies (ln(f1/f2)), weighted differences in fares (wdfa), together with a dummy variable (β_0) for Heathrow (LHR) produces the best predicted results for all the airports. The purpose of the dummy variable in modelling is such that, other factors associated with the utility function which are otherwise not included are taken into account. Therefore in the case of the short haul modelling, it can be seen that a negative constant (β_0) is required for all passenger types so that over-prediction is minimised at LHR.

Ideally the "other factors" should be included in the modelling as independent variables such as type of aircraft, ease of airport parking, etc. instead of being captured in the dummy variable. However to take the "other factors" into modelling considerations are beyond the scope of this research. Latest work by CAA (RUCATSE, 1993) have used predetermined values to represent the attraction factors associated with different airports and markets.

Results for all other passenger types are produced exactly in the same way as that of business passengers and are shown by table 7.3. The regression results by difference in access time and ratio of access time for UK leisure IT and leisure OT passengers are shown in appendix A. Appendix B shows the results for business, IT and OT for foreign passengers for the short haul model.

Short haul model

	Pax 000's	LGW	LHR	LTN	STN	BHX	MAN
UK							
Observed	BUS	936.5	5418.1	20.5	188.3	365.3	616.8
Predicted		854.8	6046.3	3.5	262.8	79.5	298.6
	IT	865.0	1272.9	23.1	35.5	64.4	212.0
		911.7	1365.2	19.3	25.3	9.7	141.6
	OT	2600.9	5865.3	177.3	242.2	297.1	593.2
		2780.9	6347.2	67.5	167.5	65.2	347.7
Foreign							
Observed	BUS	1528.2	8452.8	19.1	128.2	319.4	418.8
Predicted		1576.0	8720.1	4.1	201.0	59.7	305.5
	IT	341.0	865.3	0.5	9.2	1.1	6.0
		128.5	1080.6	0.2	8.6	1.2	4.0
	OT	2235.1	6149.2	92.4	131.7	160.4	512.7
		2058.2	6715.7	28.1	72.1	19.2	388.3

Table 7.3 Observed and Predicted Passengers at Airports

For all the passenger types coefficients determined by regression analysis (from the difference in access time equations) combining the various independent variables together with dummy variables where necessary are tested. Table 7.4 summarises the results for UK and foreign passengers the coefficients that best predict the actual passenger share for the airports. The coefficients and the respective t values for the UK business (BUS) leisure inclusive tour (IT) and leisure other (OT) passengers are shown. Coefficients for the foreign passengers are also shown in that order.

It can be seen from table 7.4 that for all passenger types the r^2 values are high, indicating there is a close fit between the dependent and independent variables. The t statistics for all coefficients are above the 99% significant level and the signs of coefficients are also of the expected order.

The k value is set to zero in the modelling for all passengers, since an airport specific constant (β_0) is used. The results show that for the short haul market dummy variables for Heathrow and Manchester are required in order to produce the best equations to predict the actual and observed passenger behaviour. In the case of LHR the dummy variables have a negative value to minimise the over prediction whereas at MAN it is positive to make MAN airport more attractive to passengers. There is a common pattern for UK and foreign passengers that dummy variables are required at LHR and MAN for the corresponding passenger types. The access time coefficients for both UK and foreign passenger types are similar in magnitude. The range of coefficients produced by the modelling in this study are compatible with the range of results obtained by others for access time. In particular results obtained by Blore (1992) and Brooke et al (1994) are very similar to those obtained in this study.

Pax type		r^2	k	dat	ln (f/f)	dfq	wdfa	dummy variables LHR	MAN
UK	**BUS**	0.591	0	-0.019	3.977		0.045	-3.907	
				8.605	*14.813*		*3.031*	*5.727*	
	IT	0.754	0	-0.018	3.109		-0.191	-5.007	3.684
				13.255	*18.536*		*13.747*	*11.459*	*11.905*
	OT	0.701	0	-0.018	2.819		-0.134	-4.057	2.26
				12.859	*16.531*		*9.453*	*9.133*	*7.186*
Foreign	**BUS**	0.688	0	-0.022		0.154	0.092	-21.098	
				12.791		*18.039*	*7.707*	*14.723*	
	IT	0.669	0	-0.028	5.134		-0.064	-6.319	
				11.567	*16.938*		*3.846*	*8.203*	
	OT	0.655	0	-0.021	3.07		-0.171	-4.314	3.765
				11.975	*13.943*		*9.393*	*7.523*	*9.272*

Table 7.4 Short Haul Model Results

There is inconsistency in that the foreign leisure IT passengers' access time and frequency coefficients are not compatible with the results of other passenger types. Also for the foreign leisure IT passengers a dummy is not required at MAN, whereas for UK leisure IT there is. A possible explanation could be that passenger origin destination for LTN, STN, BHX and MAN are extremely low compared to LGW and LHR. There is a much greater uneven distribution of leisure IT passengers amongst airports compared to the other types of passengers.

With the exception to foreign business passengers, all other equations show that logarithmic difference in frequencies produce better results for the short haul modelling. The value of the frequency coefficients for all passenger types are similar in magnitudes with the exception to foreign business and leisure IT. The foreign business frequency coefficient is expected to be different since the variable used is different i.e. difference of frequency instead of logarithmic difference.

Weighted fare difference produces better results than the simple difference in fare between airports for these market characteristics. ABC World Airways Guide give the same fare values for the London area airports (LGW, LHR, STN and LTN). Therefore it can be seen that the weighted fares produce an accurate prediction since it distinguishes between the fare levels for all airports.

Once the model coefficients are determined that predict best the observed passenger share at airports, the next objective of the thesis is to evaluate the implications of the noise charge on the change in demand at these airports. This particular issue is dealt with in the next chapter for short haul, charter and long haul markets. The data results and the discussion of the modelling for charter and long haul markets are examined in the rest of this chapter. The inner and outer London area results are discussed and shown towards the end of this chapter.

BUSINESS PAX UK SHORT HAUL MODEL

Equation 1

	r2	k	dat	dfq	wdfe
EA	0.807	0.445	-0.042	0.01	-0.237
		0.36	*5.704*	*1.339*	*3.226*
EM	0.726	-0.313	0.009	0.02	0.078
		0.396	*1.987*	*3.945*	*1.607*
GL	0.746	0.42	-0.062	0.003	-0.08
		0.296	*4.423*	*0.357*	*0.846*
N	0.298	-1.046	0.01	0.038	0.108
		0.331	*0.522*	*1.909*	*0.551*
NW	0.463	0.026	0.01	0.038	0.302
		0.011	*0.736*	*2.547*	*1.909*
SE	0.891	0.305	-0.027	0.011	0.022
		0.65	*6.265*	*3.489*	*0.691*
SW	0.558	0.365	-0.008	0.028	0.005
		0.263	*0.634*	*3.356*	*0.065*
WM	0.34	-0.259	-0.006	0.027	0.087
		0.132	*0.491*	*2.29*	*0.735*
Y	0.657	-0.539	0.028	0.034	0.288
		0.278	*2.493*	*2.799*	*2.392*
ALL	0.27	0.595	-0.014	0.027	0.03
		0.822	*3.667*	*5.97*	*0.658*

Equation 2

	r2	k	dat	f1/f2	wdfe
EA	0.833	-0.066	-0.042	0.207	-0.255
		0.059	*6.204*	*1.958*	*3.73*
EM	0.649	-0.572	0.007	0.293	0.052
		0.619	*1.194*	*3.118*	*0.961*
GL	0.747	0.296	-0.061	0.065	-0.087
		0.199	*4.345*	*0.432*	*0.901*
N	0.299	-1.763	0.002	0.622	0.038
		0.537	*0.11*	*1.916*	*0.192*
NW	0.527	-0.922	0.003	0.655	0.218
		0.383	*0.21*	*2.977*	*1.447*
SE	0.846	0.194	-0.026	0.147	0.005
		0.333	*4.792*	*2.34*	*0.119*
SW	0.612	-0.171	-0.014	0.436	-0.023
		0.13	*1.241*	*3.787*	*0.29*
WM	0.41	-0.929	-0.012	0.48	0.043
		0.483	*0.989*	*2.679*	*0.383*
Y	0.66	-1.191	0.021	0.56	0.224
		0.593	*1.788*	*2.828*	*1.844*
ALL	0.327	-0.287	-0.016	0.475	-0.013
		0.391	*4.427*	*7.069*	*0.3*

Equation 3

	r2	k	dat	ln(f1/f2)	wdfe
EA	0.878	-0.18	-0.043	1.186	-0.258
		0.189	*7.36*	*3.06*	*4.379*
EM	0.778	-0.348	-0.002	1.788	0.08
		0.492	*0.333*	*4.664*	*1.374*
GL	0.78	-0.03	-0.054	0.868	-0.111
		0.023	*3.836*	*1.354*	*1.222*
N	0.316	-1.119	-0.01	3.198	0.021
		0.369	*0.45*	*2.008*	*0.107*
NW	0.58	-0.353	-0.005	3.149	0.191
		0.162	*0.434*	*3.368*	*1.35*
SE	0.928	0.181	-0.017	1.083	-0.028
		0.466	*3.853*	*4.836*	*0.946*
SW	0.815	0.044	-0.019	2.205	-0.01
		0.061	*2.522*	*6.498*	*0.177*
WM	0.527	-0.532	-0.022	2.566	0.043
		0.322	*1.867*	*3.415*	*0.425*
Y	0.66	-0.58	0.011	2.771	0.209
		0.29	*0.829*	*2.829*	*1.711*
ALL	0.433	-0.21	-0.019	2.464	-0.011
		0.324	*5.719*	*9.146*	*0.283*

Equation 4

	r2	k	dat	dfq	dfe
EA	0.627	3.072	-0.042	0.013	-0.01
		2.277	*3.833*	*1.146*	*0.316*
EM	0.905	0.462	0	0.012	0.054
		1.051	*0.141*	*3.818*	*5.319*
GL	0.745	1.757	-0.069	-0.002	0.022
		1.446	*5.067*	*0.191*	*0.818*
N	0.518	1.949	-0.006	0.019	0.121
		0.759	*0.366*	*1.029*	*2.338*
NW	0.694	0.728	0.002	0.013	0.13
		0.424	*0.158*	*0.967*	*3.831*
SE	0.886	0.161	-0.025	0.011	0.002
		0.348	*6.431*	*3.097*	*0.215*
SW	0.747	1.843	-0.012	0.017	0.052
		2.249	*1.415*	*2.354*	*2.861*
WM	0.887	1.557	-0.014	0.011	0.09
		1.246	*1.55*	*1.152*	*3.439*
Y	0.763	0.166	0.011	0.015	0.115
		0.105	*1.098*	*1.343*	*3.635*
ALL	0.401	2.225	-0.018	0.015	0.068
		4.002	*5.074*	*3.107*	*5.409*

Equation 5

	r2	k	dat	f1/f2	dfe
EA	0.632	2.741	-0.041	0.236	-0.019
		1.807	*3.74*	*1.208*	*0.521*
EM	0.86	0.588	-0.001	0.167	0.065
		1.057	*0.272*	*2.516*	*4.348*
GL	0.748	1.991	-0.07	-0.083	0.028
		1.508	*5.196*	*0.436*	*0.93*
N	0.507	2.038	-0.009	0.277	0.119
		0.761	*0.511*	*0.879*	*2.161*
NW	0.713	0.242	-0.001	0.28	0.117
		0.139	*0.055*	*1.314*	*3.249*
SE	0.846	0.17	-0.026	0.147	0.001
		0.301	*5.475*	*2.049*	*0.062*
SW	0.74	1.069	-0.017	0.265	0.047
		1.845	*1.979*	*2.259*	*2.351*
WM	0.676	1.333	-0.016	0.208	0.084
		1.03	*1.779*	*1.296*	*3.045*
Y	0.775	-0.148	0.008	0.295	0.107
		0.092	*0.864*	*1.58*	*3.285*
ALL	0.412	1.809	-0.018	0.272	0.059
		2.972	*5.383*	*3.505*	*4.365*

Equation 6

	r2	k	dat	ln(f1/f2)	dfe
EA	0.717	1.656	-0.038	1.904	-0.05
		1.204	*3.927*	*2.28*	*1.404*
EM	0.918	0.425	-0.006	1.148	0.049
		1.044	*1.686*	*4.289*	*4.874*
GL	0.75	1.232	-0.062	0.555	0.004
		0.933	*3.874*	*0.513*	*0.108*
N	0.495	2.459	-0.012	1.206	0.119
		0.955	*0.643*	*0.714*	*1.979*
NW	0.699	0.592	-0.003	1.207	0.113
		0.343	*0.306*	*1.065*	*2.624*
SE	0.946	-0.035	-0.017	1.387	-0.018
		0.109	*5.258*	*5.711*	*2.309*
SW	0.848	1.007	-0.02	1.74	0.026
		1.437	*3.032*	*4.07*	*1.551*
WM	0.692	1.219	-0.02	1.243	0.074
		0.988	*2.133*	*1.528*	*2.479*
Y	0.757	0.32	0.005	1.262	0.106
		0.204	*0.446*	*1.229*	*2.92*
ALL	0.461	1.139	-0.02	1.61	0.037
		1.933	*6.068*	*5.039*	*2.639*

Section 7.4 Ratio of Access Time

Equation 1

	r2	k	ret	dfq	wdfa
EA	0.75	5.78	-4.375	0.006	-0.269
		3.441	*4.768*	*0.662*	*3.226*
EM	0.756	-1.378	0.395	0.019	0.033
		1.476	*2.402*	*4.019*	*0.648*
GL	0.621	9.119	-8.741	-0.004	-0.186
		2.94	*3.087*	*0.282*	*1.709*
N	0.29	-2.244	1.234	0.038	0.102
		0.433	*0.375*	*1.919*	*0.522*
NW	0.444	0.688	-0.229	0.037	0.23
		0.272	*0.37*	*2.388*	*1.255*
SE	0.857	5.215	-5.716	0.008	-0.014
		5.234	*5.244*	*2.01*	*0.398*
SW	0.601	2.038	-1.645	0.028	0.01
		1.034	*1.269*	*3.709*	*0.124*
WM	0.43	1.276	-0.675	0.028	0.106
		0.59	*1.42*	*2.519*	*0.953*
Y	0.605	-2.464	1.903	0.035	0.283
		0.978	*1.991*	*2.7*	*2.189*
ALL	0.252	1.417	-0.71	0.027	0.026
		1.748	*3.163*	*5.935*	*0.56*

Equation 2

	r2	k	ret	f1/f2	wdfa
EA	0.759	5.463	-4.342	0.114	-0.279
		3.159	*4.814*	*0.907*	*3.394*
EA	0.641	-1.138	0.245	0.282	0.026
		1.006	*1.062*	*2.727*	*0.423*
GL	0.62	8.175	-8.013	0.036	-0.19
		2.6	*2.98*	*0.183*	*1.717*
N	0.299	-1.485	-0.213	0.645	0.032
		0.288	*0.061*	*1.967*	*0.163*
NW	0.545	-0.487	-0.383	0.666	0.145
		0.203	*0.691*	*3.071*	*0.883*
SE	0.85	5.019	-5.131	0.118	-0.026
		4.448	*4.871*	*1.809*	*0.703*
SW	0.643	1.898	-1.983	0.448	-0.029
		0.901	*1.626*	*4.088*	*0.395*
WM	0.504	0.723	-0.808	0.48	0.065
		0.352	*1.801*	*2.989*	*0.628*
Y	0.62	-2.53	1.306	0.592	0.214
		1.023	*1.308*	*2.829*	*1.671*
ALL	0.307	0.712	-0.849	0.476	-0.018
		0.883	*3.904*	*6.96*	*0.408*

Equation 3

	r2	k	ret	ln(f1/f2)	wdfa
EA	0.787	5.209	-4.343	0.791	-0.281
		3.322	*5.128*	*1.551*	*3.644*
EM	0.78	-0.632	0.091	1.595	0.047
		0.707	*0.481*	*4.379*	*0.951*
GL	0.639	6.569	-6.632	0.749	-0.204
		1.918	*2.168*	*0.784*	*1.863*
N	0.326	1.387	-2.352	3.337	0.018
		0.262	*0.6*	*2.113*	*0.094*
NW	0.625	0.016	-0.623	3.111	0.111
		0.008	*1.233*	*3.709*	*0.74*
SE	0.891	3.232	-3.205	0.992	-0.051
		2.501	*2.531*	*2.938*	*1.507*
SW	0.869	2.596	-2.731	2.307	-0.018
		2.366	*3.68*	*8.041*	*0.418*
WM	0.645	1.627	-1.148	2.523	0.075
		0.973	*2.884*	*4.107*	*0.852*
Y	0.648	-1.175	0.576	2.967	0.2
		0.5	*0.54*	*3.084*	*1.615*
ALL	0.4	1.001	-0.992	2.414	-0.017
		1.361	*4.857*	*8.725*	*0.407*

Equation 4

	r2	k	ret	dfq	dfa
EA	0.537	0.799	-4.055	0.012	-0.026
		3.445	*3.11*	*0.907*	*0.728*
EM	0.905	0.578	-0.022	0.012	0.056
		0.878	*0.153*	*3.708*	*4.297*
GL	0.521	1.874	-9.306	-0.004	-0.001
		3.634	*2.922*	*0.242*	*0.016*
N	0.526	3.967	-1.698	0.019	0.125
		0.81	*0.584*	*1.044*	*2.429*
NW	0.703	1.415	-0.238	0.013	0.124
		0.813	*0.598*	*1.012*	*3.541*
SE	0.866	5.372	-5.514	0.009	-0.009
		7.061	*5.765*	*2.226*	*0.919*
SW	0.772	3.466	-1.785	0.019	0.049
		2.705	*1.863*	*2.906*	*2.885*
WM	0.753	2.894	-0.839	0.011	0.089
		2.278	*2.659*	*1.345*	*4.054*
Y	0.751	-0.206	0.618	0.015	0.12
		0.094	*0.778*	*1.305*	*3.744*
ALL	0.367	3.132	-0.868	0.016	0.062
		4.643	*4.153*	*3.274*	*4.912*

Equation 5

	r2	k	ret	f1/f2	dfa
EA	0.531	7.705	-3.933	0.165	-0.031
		2.933	*2.938*	*0.825*	*0.769*
EM	0.878	1.154	-0.208	0.178	0.066
		1.706	*1.301*	*2.865*	*4.688*
GL	0.518	11.339	-8.916	-0.01	-0.004
		3.488	*2.977*	*0.037*	*0.093*
N	0.518	4.511	-2.162	0.293	0.122
		0.927	*0.725*	*0.936*	*2.244*
NW	0.727	0.797	-0.265	0.299	0.109
		0.449	*0.744*	*1.438*	*2.932*
SE	0.861	0.531	-5.62	0.143	-0.013
		6.531	*5.854*	*2.098*	*1.188*
SW	0.749	3.592	-2.106	0.294	0.043
		2.664	*2.108*	*2.571*	*2.198*
WM	0.759	2.719	-0.886	0.202	0.083
		2.103	*2.842*	*1.469*	*3.531*
Y	0.766	-0.32	0.405	0.303	0.111
		0.153	*0.515*	*1.582*	*3.37*
ALL	0.377	2.787	-0.928	0.29	0.053
		3.946	*4.481*	*3.627*	*3.875*

Equation 6

	r2	k	ret	ln(f1/f2)	dfa
EA	0.613	6.046	-3.566	1.765	-0.063
		2.423	*2.887*	*1.772*	*1.53*
EM	0.912	0.865	-0.187	0.996	0.055
		1.459	*1.39*	*3.943*	*4.319*
GL	0.54	8.365	-6.807	1.176	-0.032
		1.863	*1.77*	*0.714*	*0.641*
N	0.509	5.522	2.798	1.342	0.12
		1.152	*0.851*	*0.808*	*2.027*
NW	0.722	1.029	-0.418	1.467	0.095
		0.6	*1.017*	*1.369*	*2.148*
SE	0.92	3.487	-3.668	1.298	-0.025
		3.948	*3.845*	*3.961*	*2.656*
SW	0.884	3.402	-2.702	1.97	0.019
		3.906	*3.924*	*5.203*	*1.248*
WM	0.782	2.098	-1.034	1.247	0.071
		2.325	*3.32*	*1.885*	*2.846*
Y	0.754	0.26	0.158	1.388	0.107
		0.127	*0.182*	*1.363*	*2.908*
ALL	0.421	2.294	-1.007	1.83	0.033
		3.39	*5.016*	*4.902*	*2.245*

7.5 Charter Model

Identical to the short haul model passengers are divided into six categories for the charter model. Since there is no origin destination charter passengers at Heathrow airport, modelling is carried out for the remaining five LGW, LTN, STN, BHX and MAN airports. Passenger origin destination data for LGW, LTN, STN airports are obtained from CAP 610 whilst for BHX and MAN from CAP 618, which contains the latest passenger surveys carried out at these airports. Table 7.5 shows the total passengers travelling on charter destinations from these airports. Analysis based similar to the short haul model passengers are disaggregated by types i.e., UK and foreign business, leisure IT and leisure OT.

Total International Charter Passengers

	LGW	LTN	STN	BHX	MAN
EA	304500	99333	124841	5381	5442
EM	296400	161948	34917	312265	294347
GL	2867400	257779	214477	204	204
N	46100	7545	1916	15986	390903
NW	83500	7265	6881	18754	3386350
SE	3239600	465946	205526	55043	63383
SW	702400	36505	9390	76478	26048
WM	245400	67617	5928	1052086	558167
Y	130901	28399	10816	55592	1662302
TOTAL	7916201	1132337	614692	1591789	6387146

Table 7.5

7.5.1 Routes, Access Costs, Frequencies and Fares

Five routes Faro, Lyon, Malaga, Malta and Munich are selected to represent the charter market. These routes are some of the highest passenger carrying routes for the charter destinations. The same access costs as that of the short haul are used for the charter model, since it is unlikely that access costs valued in time (min) would be any different because passengers travel to different destinations. Unlike the short haul model where the average of six routes were taken, frequencies of services from these airports to the charter market as a total are obtained from CAP 614. Therefore instead of using average frequencies the total frequencies were used for the charter model.

The fares used were the average of the five routes. Initially published "Y" fares from the ABC 1994 guide for each of the routes are collected. For the same routes actual fares are obtained from travel agents. The percentage difference between ABC Guide fares and the actual fares from travel agents for each of the routes are discounted from the ABC guide fares. The average of these discounted fares over the five routes are taken for modelling. The reason is to obtain different fares for London area airports (LGW, STN and LTN) and this process produced more realistic fares than the published ABC fares for the chosen routes. Table 7.6 shows the frequencies and fares used for the five airports for the charter model.

	Fq	Fares (£)
LGW	496	109
LTN	100	175
STN	55	126
BHX	98	143
MAN	366	137

Table 7.6 Frequencies and Fares from Airports

7.5.2 Analysis Results for Regional and all Airports

In a similar process to the short haul model all regions are regressed independently and the aggregation of all regions regressed. The regression results by difference in access time and ratio of access time for charter UK business passengers are shown by tables in section 7.6 and 7.7. The regression results for charter by difference and ratio of access times for charter UK leisure IT and leisure OT are shown in Appendix C. The corresponding results for the charter foreign passengers are shown in Appendix D.

Using the same criteria as for the short haul model for different passenger types i.e., expected signs of access and frequency coefficients for business passengers negative and positive respectively. For leisure passengers access and fare coefficients negative while frequency positive and the *t* significance at the 95% confidence level. Based on these criteria the differences in access time equations are better than the ratio of access time equations. Thus the best equation from the six equations from the difference in access time (dat) group is taken to predict the actual observed passenger share at airports.

The summary of results for the charter modelling is shown by table 7.7. For all UK passengers *t* significance is above the 99% confidence level and the sign of coefficients for access and frequency are of the expected type. For the UK leisure IT and OT passengers a dummy at LGW is used for best model prediction. Although these combination of coefficients produced the best results, the weighted fare difference coefficients are not negative. Various other combinations failed to predict better results for the observed passenger share, therefore best prediction of observed passenger share at airports are obtained with these coefficients. Despite having the wrong signs for the fare coefficients, the implications of the noise cost is to be examined with these coefficients for the UK leisure IT and OT passengers.

For the foreign passengers the *t* significance is above the 95% confidence level, with the exception to fare coefficient for the business passengers and the signs of the coefficients are of the expected types for all variables. The *t* value being very low for the fare coefficient for the foreign business passengers implies that fare is the least important factor in airport choice.

Charter Model

Pax type		r^2	k	dat	ln (f/f)	dfq	wdfa	dfa	dummy LGW
UK	BUS	0.435	0	-0.023		0.008	-0.039		
				6.814		*4.946*	*3.369*		
	IT	0.657	0	-0.021	1.468		0.018		1.941
				13.501	*8.386*		*3.045*		*5.974*
	OT	0.684	0	-0.019	1.162		0.015		2.555
				12.014	*6.684*		*2.643*		*7.917*
Foreign	BUS	0.552	0	-0.008		0.014	0.001		
				3.008		*10.482*	*0.134*		
	IT	0.21	0	-0.012	1.109			-0.033	
				3.122	*2.56*			*2.048*	
	OT	0.333	0	-0.009	1.326			-0.029	
				3.301	*4.104*			*2.357*	

Table 7.7 Charter Model Result

The constant k, like the short haul model is set to zero since airport specific constants are involved. For all UK passengers the access time coefficients are of the same magnitude and all foreign passengers access time coefficients are of the same magnitude. UK passengers' access time coefficients are similar to that obtained for the short haul model. This implies passengers travelling on the charter destinations attach an equivalent amount of importance to access time to those travelling on the short haul routes. Possibly this could be due to the fact that most of the charter routes are of equivalent flight stage length as the short haul routes.

The size of the frequency coefficients are similar for business, IT and OT passengers both UK and foreign. The frequency coefficients for the charter model are lower than the short haul model and are more in agreement with results of other airport choice modelling work. For the short haul model the frequency difference between the highest at LHR and other airports is substantially larger than the difference between the highest at LGW for the charter model than any other airport. This accounts for the relative difference in size between the frequency coefficients for the short haul and charter models.

A combination of the weighted fare and the difference in fare coefficients produces better results for the observed and predicted passenger shares at all airports. Unlike the short haul model where fares are assumed to be the same for the London area airports, for the charter market fare differences are obtained for the London area airports. Thus it can be argued that weighted fares or differences of fares coefficients both can lead to the best results for modelling.

The modelling results with the coefficients shown by table 7.7 for the charter market, are used for the evaluation of implication of passenger demand at the airports. The observed and predicted passenger shares for the chosen airports with these coefficient values are shown by table 7.8. The implications of the noise charge using these results on passenger demand are discussed in the next chapter.

Charter Model

	Pax 000's	LGW	LTN	STN	BHX	MAN
UK						
Observed	BUS	110.1	8.0	4.1	15.1	37.6
Predicted		111.1	8.7	0.3	4.2	50.7
	IT	4401.2	722.8	337.0	1286.4	4964.0
		5411.9	538.9	214.7	640.4	4905.5
	OT	2483.6	310.0	140.0	271.1	1259.8
		2879.6	177.8	84.5	204.5	1118.1
Foreign						
Observed	BUS	58.4	5.0	21.7	5.7	9.7
Predicted		86.8	0.4	0.2	0.4	12.7
	IT	268.2	32.0	77.9	3.8	18.4
		321.9	22.9	3.9	13.4	38.3
	OT	594.7	54.6	34.0	9.7	97.6
		586.6	40.7	5.0	25.3	133.0

Table 7.8 Observed and Predicted Passenger Shares at Airports

Section 7.6 Difference in Access Time

BUSINESS PAX UK CHARTER MODEL

Equation 1

	r2	k	dst	dfq	wdfa
EA	0.522	0.536	-0.095	0.01	-0.15
		0.286	*2.479*	*1.638*	*2.121*
EM	0.857	-2.587	0.024	-0.013	-0.188
		2.001	*1.069*	*1.231*	*3.137*
GL	0.425	5.837	0.006	0.011	0.085
		4.071	*0.447*	*1.624*	*1.796*
N	0.802	-3.035	0.024	-0.008	-0.168
		1.687	*2.064*	*0.924*	*2.999*
NW	0.804	-0.877	-0.008	0.017	-0.017
		0.403	*0.6*	*2.399*	*0.298*
SE	0.718	2.779	-0.025	0.004	0.033
		3.002	*3.798*	*0.846*	*1.044*
SW	0.198	5.01	-0.109	0.019	0.2
		2	*1.199*	*1.06*	*1.098*
WM	0.937	-2.446	0.015	-0.005	-0.182
		4.24	*2.616*	*1.804*	*7.885*
Y	0.855	3.368	-0.047	0.023	-0.004
		2.066	*3.026*	*3.279*	*0.076*
ALL	0.269	1.663	-0.014	0.007	-0.024
		3.192	*3.076*	*2.846*	*1.283*

Equation 2

	r2	k	dst	f1/f2	wdfa
EA	0.313	1.982	-0.054	0.138	-0.102
		0.682	*1.334*	*0.208*	*1.29*
EM	0.826	-1.67	-0.006	0.253	-0.11
		1.436	*0.442*	*0.408*	*2.723*
GL	0.229	4.833	0.012	0.481	0.062
		2.36	*0.91*	*0.666*	*1.086*
N	0.799	-1.428	0.019	-0.488	-0.151
		1.026	*2.408*	*0.867*	*3.622*
NW	0.779	-1.428	0.019	-0.488	-0.151
		1.026	*2.408*	*0.867*	*3.622*
SE	0.685	2.636	-0.024	0.07	0.019
		2.166	*3.603*	*0.16*	*0.649*
SW	0.11	2.338	-0.04	0.615	0.068
		1.137	*0.844*	*0.64*	*0.701*
WM	0.911	-1.942	0.014	-0.23	-0.149
		2.336	*1.909*	*0.703*	*6.768*
Y	0.645	-0.347	-0.022	0.868	-0.081
		0.169	*1.048*	*0.904*	*1.148*
ALL	0.248	0.69	-0.01	0.433	-0.039
		1.066	*2.364*	*1.726*	*2.064*

Equation 3

	r2	k	dst	ln(f1/f2)	wdfa
EA	0.563	0.336	-0.115	3.233	-0.155
		0.186	*2.664*	*1.874*	*2.289*
EM	0.843	-2.425	0.013	-1.833	-0.178
		1.679	*0.703*	*0.912*	*2.86*
GL	0.347	6.056	0.006	2.271	0.095
		4.032	*0.41*	*1.271*	*1.673*
N	0.78	-2.516	0.019	-0.835	-0.149
		1.233	*1.686*	*0.417*	*2.17*
NW	0.797	-0.831	-0.003	3.614	-0.004
		0.371	*0.27*	*2.322*	*0.067*
SE	0.706	2.904	-0.025	0.717	0.036
		2.997	*3.687*	*0.678*	*0.922*
SW	0.069	3.941	-0.048	1.491	0.066
		1.272	*0.567*	*0.367*	*0.426*
WM	0.928	-2.569	0.014	-0.962	-0.164
		3.996	*2.209*	*1.43*	*6.44*
Y	0.828	3.516	-0.037	4.657	0.012
		1.894	*2.469*	*2.821*	*0.203*
ALL	0.278	1.965	-0.013	1.632	-0.015
		3.444	*2.909*	*2.673*	*0.67*

Equation 4

	r2	k	dst	dfq	dfa
EA	0.556	0.359	-0.087	0.008	-0.164
		0.198	*2.67*	*1.464*	*2.306*
EM	0.813	-2.629	0.013	-0.009	-0.189
		1.664	*0.638*	*0.766*	*2.646*
GL	0.374	5.856	0.006	0.011	0.092
		3.881	*0.433*	*1.492*	*1.676*
N	0.777	-3.039	0.02	-0.006	-0.177
		1.663	*1.726*	*0.691*	*2.706*
NW	0.804	-0.881	-0.008	0.017	-0.019
		0.404	*0.678*	*2.447*	*0.3*
SE	0.709	2.864	-0.025	0.003	0.036
		2.92	*3.731*	*0.787*	*0.934*
SW	0.127	4.638	-0.073	0.013	0.149
		1.668	*0.916*	*0.76*	*0.794*
WM	0.905	-2.971	0.014	-0.005	-0.186
		3.962	*1.985*	*1.698*	*6.247*
Y	0.857	3.146	-0.045	0.022	-0.014
		1.868	*3.026*	*3.122*	*0.262*
ALL	0.292	1.563	-0.014	0.007	-0.031
		2.816	*3.079*	*2.633*	*1.421*

Equation 5

	r2	k	dst	f1/f2	dfa
EA	0.401	1.368	-0.058	0.104	-0.134
		0.608	*1.66*	*0.172*	*1.869*
EM	0.806	-2.067	-0.01	0.374	-0.117
		1.74	*0.707*	*0.689*	*2.464*
GL	0.182	5.056	0.012	0.409	0.06
		2.414	*0.869*	*0.641*	*0.877*
N	0.778	-1.745	0.016	-0.417	-0.165
		1.198	*2.066*	*0.707*	*3.27*
NW	0.778	-4.995	0.003	1.238	-0.059
		2.74	*0.311*	*2.148*	*1.061*
SE	0.679	2.711	-0.024	0.037	0.017
		2.227	*3.469*	*0.062*	*0.42*
SW	0.069	2.546	-0.033	0.513	0.062
		1.247	*0.762*	*0.642*	*0.69*
WM	0.871	-2.401	0.013	-0.214	-0.166
		2.437	*1.487*	*0.634*	*4.6*
Y	0.665	-0.54	-0.023	0.761	-0.102
		0.265	*1.128*	*0.86*	*1.327*
ALL	0.255	0.593	-0.01	0.369	-0.05
		0.928	*2.417*	*1.644*	*2.264*

Equation 6

	r2	k	dst	ln(f1/f2)	dfa
EA	0.569	0.213	-0.103	2.618	-0.167
		0.122	*2.786*	*1.669*	*2.436*
EM	0.802	-2.355	0.004	-1.013	-0.172
		1.376	*0.199*	*0.476*	*2.291*
GL	0.283	6.252	0.006	2.094	0.098
		3.7	*0.426*	*1.086*	*1.309*
N	0.761	-2.414	0.015	-0.403	-0.152
		1.106	*1.418*	*0.202*	*1.962*
NW	0.797	-0.837	-0.003	3.612	-0.005
		0.374	*0.299*	*2.369*	*0.071*
SE	0.696	2.973	-0.025	0.647	0.036
		2.814	*3.6*	*0.681*	*0.779*
SW	0.049	3.448	-0.029	0.587	0.045
		1.067	*0.411*	*0.169*	*0.23*
WM	0.89	-3.108	0.013	-1.014	-0.187
		3.696	*1.699*	*1.18*	*6.018*
Y	0.825	3.249	-0.036	4.356	-0.001
		1.666	*2.417*	*2.626*	*0.009*
ALL	0.28	1.835	-0.013	1.511	-0.023
		2.98	*2.891*	*2.327*	*0.873*

Section 7.7 Ratio of Access Time

Equation 1

	r2	k	rwt	dfq	wdfe
EA	0.374	9.375	-5.302	0.001	-0.084
		3.316	*1.81*	*0.147*	*1.356*
EM	0.867	-3.3	0.755	-0.01	-0.176
		2.64	*1.749*	*1.85*	*5.132*
GL	0.486	8.73	-4.628	0.01	0.041
		2.44	*0.972*	*1.677*	*0.632*
N	0.853	9.52	-6.451	0.018	-0.011
		2.698	*2.794*	*3.112*	*0.262*
NW	0.812	-0.703	-0.37	0.013	-0.034
		0.365	*0.809*	*2.736*	*0.886*
SE	0.625	10.428	-10.428	-0.009	-0.036
		4.295	*3.062*	*1.551*	*0.869*
SW	0.581	19.82	-13.666	0.02	0.18
		3.26	*2.874*	*2.223*	*2.355*
WM	0.93	1.339	-1.169	0.006	-0.081
		0.845	*2.262*	*1.297*	*2.303*
Y	0.844	6.308	-3.174	0.018	-0.023
		2.423	*2.836*	*2.927*	*0.493*
ALL	0.384	3.552	-1.352	0.007	-0.021
		5.282	*4.914*	*3.169*	*1.256*

Equation 2

	r2	k	rwt	f1/f2	wdfe
EA	0.375	9.423	-5.585	0.112	-0.087
		3.306	*1.698*	*0.189*	*1.431*
EM	0.823	-1.652	0.131	-0.055	-0.126
		1.398	*0.336*	*0.106*	*3.486*
GL	0.274	9.117	-6.287	0.352	-0.006
		1.936	*1.122*	*0.488*	*0.082*
N	0.647	2.606	-2.548	0.551	-0.082
		0.643	*0.864*	*0.731*	*1.434*
NW	0.788	-3.31	-0.316	1.273	-0.036
		1.41	*0.647*	*2.439*	*0.866*
SE	0.633	12.489	-10.857	-0.937	-0.042
		3.939	*3.111*	*1.612*	*0.972*
SW	0.35	10.053	-7.066	0.757	0.08
		2.194	*1.789*	*1.029*	*1.211*
WM	0.931	-0.416	-0.821	0.407	-0.087
		0.439	*2.64*	*1.312*	*3.943*
Y	0.854	1.792	-1.647	0.611	-0.093
		0.659	*1.136*	*0.76*	*1.462*
ALL	0.341	2.376	-1.187	0.445	-0.035
		3.268	*4.304*	*1.967*	*1.976*

Equation 3

	r2	k	rwt	ln(f1/f2)	wdfe
EA	0.372	9.376	-5.265	0.11	-0.085
		3.15	*1.763*	*0.069*	*1.329*
EM	0.864	-3.693	0.72	-2.429	-0.193
		2.553	*1.679*	*1.78*	*4.424*
GL	0.46	9.929	-5.709	2.28	0.046
		2.791	*1.206*	*1.543*	*0.651*
N	0.828	8.38	-5.184	3.76	0.003
		2.302	*2.294*	*2.717*	*0.054*
NW	0.802	-0.597	-0.222	3.229	-0.014
		0.302	*0.463*	*2.605*	*0.299*
SE	0.625	9.6	-9.728	-1.995	-0.048
		4.296	*3.057*	*1.554*	*1.012*
SW	0.445	18.236	-11.843	3.744	0.177
		2.445	*2.146*	*1.504*	*1.657*
WM	0.929	1.409	-1.097	1.406	-0.074
		0.835	*2.249*	*1.237*	*1.789*
Y	0.826	6.076	-2.698	3.977	-0.004
		2.219	*2.455*	*2.658*	*0.079*
ALL	0.37	3.755	-1.302	1.551	-0.014
		5.269	*4.718*	*2.811*	*0.668*

Equation 4

	r2	k	rwt	dfq	dfe
EA	0.422	9.036	-5.318	0	-0.104
		3.676	*2.018*	*0.028*	*1.678*
EM	0.862	-3.961	0.775	-0.012	-0.207
		2.632	*1.694*	*1.756*	*4.624*
GL	0.472	9.269	-5.303	0.01	0.035
		2.746	*1.164*	*1.63*	*0.473*
N	0.856	9.11	-6.243	0.017	-0.021
		2.612	*2.807*	*2.967*	*0.442*
NW	0.812	-0.751	-0.391	0.013	-0.04
		0.384	*0.866*	*2.601*	*0.881*
SE	0.621	10.205	-10.228	-0.009	-0.04
		4.289	*3.061*	*1.607*	*0.828*
SW	0.509	18.396	-12.121	0.018	0.182
		2.833	*2.482*	*1.863*	*1.963*
WM	0.925	1.449	-1.296	0.007	-0.086
		0.872	*2.654*	*1.402*	*2.106*
Y	0.848	6.032	-3.113	0.018	-0.034
		2.309	*2.881*	*2.79*	*0.648*
ALL	0.386	3.435	-1.346	0.007	-0.028
		4.936	*4.914*	*2.929*	*1.393*

Equation 5

	r2	k	rwt	f1/f2	dfe
EA	0.422	9.09	-5.444	0.037	-0.104
		3.709	*1.764*	*0.066*	*1.644*
EM	0.791	-1.994	0.08	-0.012	-0.139
		1.556	*0.19*	*0.021*	*3.062*
GL	0.282	9.566	-6.872	0.265	-0.022
		2.214	*1.301*	*0.366*	*0.261*
N	0.669	2.522	-2.648	0.485	-0.101
		0.646	*0.942*	*0.669*	*1.613*
NW	0.791	-3.341	-0.332	1.24	-0.044
		1.434	*0.693*	*2.344*	*0.926*
SE	0.623	12.072	-10.512	-0.869	-0.043
		3.94	*3.068*	*1.521*	*0.866*
SW	0.317	9.614	-6.434	0.675	0.079
		2.069	*1.669*	*0.899*	*0.049*
WM	0.923	-0.51	-0.92	0.439	-0.107
		0.608	*2.799*	*1.363*	*3.667*
Y	0.676	1.644	-1.697	0.53	-0.115
		0.629	*1.232*	*0.669*	*1.629*
ALL	0.348	2.294	-1.198	0.4	-0.045
		3.182	*4.346*	*1.743*	*2.206*

Equation 6

	r2	k	rwt	ln(f1/f2)	dfe
EA	0.422	8.951	-5.261	-0.112	-0.106
		3.409	*1.96*	*0.092*	*1.663*
EM	0.848	-4.208	0.669	-2.426	-0.218
		2.306	*1.362*	*1.488*	*3.666*
GL	0.443	10.453	-6.394	2.135	0.038
		3.07	*1.399*	*1.381*	*0.477*
N	0.828	7.892	-4.936	3.513	-0.009
		2.183	*2.266*	*2.632*	*0.163*
NW	0.802	-0.624	-0.231	3.2	-0.016
		0.311	*0.486*	*2.473*	*0.306*
SE	0.619	9.304	-9.49	-1.966	-0.053
		4.187	*3.023*	*1.492*	*0.961*
SW	0.365	15.866	-9.735	2.971	0.159
		2.071	*1.799*	*1.149*	*1.281*
WM	0.925	1.572	-1.221	1.59	-0.076
		0.913	*2.646*	*1.414*	*1.643*
Y	0.828	5.753	-2.615	3.745	-0.017
		2.076	*2.466*	*2.479*	*0.261*
ALL	0.372	3.623	-1.291	1.442	-0.04
		4.843	*4.706*	*2.536*	*0.876*

7.8 Long Haul Model

For the long haul modelling Gatwick Heathrow and Manchester airports are chosen. The aircraft types used for long haul routes and the number of movements for which the noise landing charge is developed are limited for the other airports. Better results are produced with models for LGW, LHR and MAN only. However due to the limited number of airports for long haul modelling, regression analysis is based on a data size that is much smaller than the other models.

The same access costs as the short haul and charter model are used for the long haul model. The data on total frequencies served on the long haul routes from LGW and LHR were obtained from the airports. For MAN airport four routes Abu Dhabi (AUH), Johannesburg (JNB), New York (NYC) and Singapore (SIN) are taken to represent the long haul market frequencies. For modelling, average frequency per week is used for all the airports. The average of the economy "Y" fares on these routes are used from the ABC World Airways Guide of March 1994. The frequencies per week and the average fares used for the long haul model are shown by table 7.9.

	fq/wk	Average fares (£)
LGW	385	553
LHR	750	553
MAN	185	664

Table 7.9 Frequencies and Fares for Long Haul Model

7.8.1 Analysis Results

The sample size compared to the short haul and charter models are smaller for the long haul model. Therefore the aggregate of all regions are regressed instead of regressing regions independently. Assessment criteria is based on prior expectation of signs of coefficients and the *t* significance as for the short haul and charter model for business, leisure IT and OT passengers. There appears to be no consistency between difference and ratio of access time equations for both UK and foreign passengers. However for all the passenger types the coefficient of determination r^2, and the *t* significance for the difference of access time equations are substantially higher than the ratio of access time equations. Therefore the best equation from the six access time equations are taken to reproduce the observed passenger share at airports.

The regression results for UK passengers are shown by the tables in section 7.9 and the results for foreign passengers are shown by the tables in section 7.10. Table 7.10 shows the summary of results that produce the best observed and predicted share at airports for the long haul model.

Long Haul Model

									dummy variables	
Passenger types		**r^2**	**k**	**dat**	**ln (f/f)**	**dfq**	**wdfa**	**dfa**	**LHR**	**LGW**
UK	**BUS**	0.821	0	-0.037		0.001	-0.091			
				12.26		*0.25*	*7.098*			
	IT	0.822	0	-0.01		0.001	-0.062			
				6.657		*0.342*	*9.417*			
	OT	0.841	0	-0.029		0.004	-0.045			2.000
				11.812		*0.000*	*0.000*			*0.000*
Foreign	**BUS**	0.914	0	-0.029	0.637		-0.049			
				23.385	*2.135*		*6.911*			
	IT	0.285	-0.251	-0.006	2.45			-0.044		
			0.247	*2.096*	*2.384*			*3.604*		
	OT	0.911	0	-0.026		0.013	-0.023		-5.143	
				17.219		*0.000*	*0.000*		*0.000*	

Table 7.10 Long Haul Model Results

From table 7.10 it can be seen that for the UK passenger types there is consistency that difference in frequency and weighted fares produce the best combinations of results for modelling. However the *t* ratios for the frequency coefficients are not significant for the UK passengers. For the foreign passengers the logarithmic difference in frequencies for business and leisure IT produce statistically significant coefficients at the 95% confidence level. For both UK and foreign leisure OT passengers the *t* significance for frequency and weighted difference in fares are low. This could be due to observed passenger share for MAN being very low compared to LGW and LHR. There are similarities between the access time coefficients for all the three models. For most of the passenger types the size of the coefficients for access times are within compatible ranges.

The results shown by table 7.10 for all passenger types produce best the observed passengers at airports. Therefore modelling for implication of noise charge is carried out with these coefficients values. This is demonstrated in the next chapter.

Section 7.9

Long Haul Model for UK passengers

	Equation 1					Equation 2					Equation 3				
BUS	r2	k	dat	dfq	wdfa	r2	k	dat	f1/f2	wdfa	r2	k	dat	ln(f1/f2)	wdfa
	0.759	0	-0.037	0	-0.091	0.759	-0.001	-0.037	-0.054	-0.092	0.759	0	-0.037	-0.16	-0.092
		0	*8.242*	*0.089*	*4.363*		*0.001*	*8.242*	*0.089*	*3.661*		*0*	*8.242*	*0.089*	*3.604*
	r2	k	rat	dfq	wdfa	r2	k	rat	f1/f2	wdfa	r2	k	rat	ln(f1/f2)	wdfa
	0.564	2.612	-1.987	0.001	-0.086	0.564	2.618	-1.987	0.261	-0.081	0.564	2.612	-1.987	0.772	-0.08
		1.298	*5.211*	*0.32*	*3.023*		*1.312*	*5.211*	*0.32*	*2.379*		*1.298*	*5.211*	*0.32*	*3.023*
IT	r2	k	dat	dfq	wdfa	r2	k	dat	f1/f2	wdfa	r2	k	dat	ln(f1/f2)	wdfa
	0.642	0	-0.01	0	-0.061	0.642	-0.001	-0.01	-0.04	-0.062	0.642	0	-0.01	-0.117	-0.062
		0	*4.471*	*0.128*	*5.788*		*0.001*	*4.471*	*0.128*	*4.862*		*0*	*4.471*	*0.128*	*4.786*
	r2	k	rat	dfq	wdfa	r2	k	rat	f1/f2	wdfa	r2	k	rat	ln(f1/f2)	wdfa
	0.452	0.53	-0.403	0	-0.056	0.452	0.532	-0.403	0.089	-0.054	0.452	0.53	-0.403	0.263	-0.054
		0.563	*2.262*	*0.234*	*4.227*		*0.57*	*2.262*	*0.234*	*3.427*		*0.563*	*2.262*	*0.234*	*3.366*
OT	r2	k	dat	dfq	wdfa	r2	k	dat	f1/f2	wdfa	r2	k	dat	ln(f1/f2)	wdfa
	0.77	0	-0.029	-0.002	-0.104	0.77	-0.009	-0.029	-0.35	-0.11	0.77	0	-0.029	-1.036	-0.111
		0	*8.013*	*0.697*	*6.025*		*0.007*	*8.013*	*0.697*	*5.327*		*0*	*8.013*	*0.697*	*5.26*
	r2	k	rat	dfq	wdfa	r2	k	rat	f1/f2	wdfa	r2	k	rat	ln(f1/f2)	wdfa
	0.575	2.053	-1.562	0	-0.098	0.575	2.051	-1.562	-0.088	-0.1	0.575	2.053	-1.562	-0.261	-0.1
		1.225	*4.918*	*0.13*	*4.174*		*1.233*	*4.918*	*0.13*	*3.554*		*1.225*	*4.918*	*0.13*	*3.501*

Equation 4

r2	k	dat	dfq	dfa
0.759	0	-0.037	0	-0.043
	0	*8.242*	*0.089*	*4.363*

r2	k	rat	dfq	dfa
0.564	2.612	-1.987	0.001	-0.04
	1.298	*5.211*	*0.32*	*3.023*

r2	k	dat	dfq	dfa
0.642	0	-0.01	0	-0.029
	0	*4.471*	*0.128*	*5.788*

r2	k	rat	dfq	dfa
0.452	0.53	-0.403	0	-0.026
	0.563	*2.262*	*0.234*	*4.227*

r2	k	dat	dfq	dfa
0.77	0	-0.029	-0.002	-0.049
	0	*8.013*	*0.697*	*6.025*

r2	k	rat	dfq	dfa
0.575	2.053	-1.562	0	-0.047
	1.225	*4.918*	*0.13*	*4.174*

Equation 5

r2	k	dat	f1/f2	dfa
0.759	-0.001	-0.037	-0.054	-0.044
	0.001	*8.242*	*0.089*	*3.661*

r2	k	rat	f1/f2	dfa
0.564	2.618	-1.987	0.261	-0.038
	1.312	*5.211*	*0.32*	*2.379*

r2	k	dat	f1/f2	dfa
0.642	-0.001	-0.01	-0.04	-0.029
	0.001	*4.471*	*0.128*	*4.862*

r2	k	rat	f1/f2	dfa
0.452	0.532	-0.403	0.089	-0.026
	0.57	*2.262*	*0.234*	*3.427*

r2	k	dat	f1/f2	dfa
0.77	-0.009	-0.029	-0.35	-0.052
	0.007	*8.013*	*0.697*	*5.327*

r2	k	rat	f1/f2	dfa
0.575	2.051	-1.562	-0.088	-0.047
	1.233	*4.918*	*0.13*	*3.554*

Equation 6

r2	k	dat	ln(f1/f2)	dfa
0.759	0	-0.037	-0.16	-0.044
	0	*8.242*	*0.089*	*3.604*

r2	k	rat	ln(f1/f2)	dfa
0.564	2.612	-1.987	0.772	-0.038
	1.298	*5.211*	*0.32*	*2.332*

r2	k	dat	ln(f1/f2)	dfa
0.285	-0.251	-0.006	2.45	-0.044
	0.247	*2.096*	*2.384*	*3.604*

r2	k	rat	ln(f1/f2)	dfa
0.452	0.53	-0.403	0.263	-0.026
	0.563	*2.262*	*0.234*	*3.366*

r2	k	dat	ln(f1/f2)	dfa
0.77	0	-0.029	-1.036	-0.052
	0	*8.013*	*0.697*	*5.26*

r2	k	rat	ln(f1/f2)	dfa
0.575	2.053	-1.562	-0.261	-0.047
	1.225	*4.918*	*0.13*	*3.501*

Section 7.10

Long Haul Model for Foreign passengers

Equation 1

	r2	k	dat / rat	dfq	wdfa
BUS	r2	k	dat	dfq	wdfa
	0.919	0	-0.029	0.001	-0.054
		0	*15.564*	*0.817*	*6.209*
	r2	k	rat	dfq	wdfa
	0.673	2.053	-1.562	0.002	-0.05
		1.65	*6.625*	*0.909*	*2.821*
IT	r2	k	dat	dfq	wdfa
	0.736	0	-0.038	-0.002	-0.13
		0	*7.382*	*0.442*	*5.302*
	r2	k	rat	dfq	wdfa
	0.415	2.24	-1.704	0.001	-0.114
		0.863	*3.468*	*0.116*	*3.099*
OT	r2	k	dat	dfq	wdfa
	0.867	0	-0.026	-0.001	-0.078
		0	*11.618*	*0.455*	*7.315*
	r2	k	rat	dfq	wdfa
	0.668	1.901	-1.446	0	-0.075
		1.578	*6.339*	*0.163*	*4.39*

Equation 2

	r2	k	dat / rat	f1/f2	wdfa
BUS	r2	k	dat	f1/f2	wdfa
	0.919	0.005	-0.029	0.207	-0.05
		0.009	*15.654*	*0.817*	*4.764*
	r2	k	rat	f1/f2	wdfa
	0.673	2.065	-1.562	0.458	-0.041
		1.673	*6.625*	*0.909*	*1.934*
IT	r2	k	dat	f1/f2	wdfa
	0.736	-0.008	-0.038	-0.314	-0.136
		0.005	*7.382*	*0.442*	*4.607*
	r2	k	rat	f1/f2	wdfa
	0.415	2.243	-1.704	0.122	-0.111
		0.872	*3.468*	*0.116*	*2.539*
OT	r2	k	dat	f1/f2	wdfa
	0.867	-0.004	-0.026	-0.141	-0.081
		0.005	*11.618*	*0.455*	*6.283*
	r2	k	rat	f1/f2	wdfa
	0.668	1.903	-1.446	0.08	-0.073
		1.593	*6.339*	*0.163*	*3.596*

Equation 3

	r2	k	dat / rat	ln(f1/f2)	wdfa
BUS	r2	k	dat	ln(f1/f2)	wdfa
	0.919	0	-0.029	0.612	-0.05
		0	*15.564*	*0.817*	*4.663*
	r2	k	rat	ln(f1/f2)	wdfa
	0.673	2.053	-1.562	1.354	-0.04
		1.65	*6.625*	*0.909*	*1.877*
IT	r2	k	dat	ln(f1/f2)	wdfa
	0.736	0	-0.038	-0.929	-0.136
		0	*7.382*	*0.442*	*4.544*
	r2	k	rat	ln(f1/f2)	wdfa
	0.415	2.24	-1.704	0.36	-0.111
		0.863	*3.468*	*0.116*	*2.496*
OT	r2	k	dat	ln(f1/f2)	wdfa
	0.867	0	-0.026	-0.418	-0.081
		0	*11.618*	*0.455*	*6.193*
	r2	k	rat	ln(f1/f2)	wdfa
	0.668	1.901	-1.446	0.235	-0.073
		1.578	*6.339*	*0.163*	*3.535*

Equation 4

r2	k	dat	dfq	dfa
0.919	0	-0.029	0.001	-0.025
	0	*15.564*	*0.817*	*6.209*

r2	k	rat	dfq	dfa
0.673	2.053	-1.562	0.002	-0.023
	1.65	*6.625*	*0.909*	*2.821*

r2	k	dat	dfq	dfa
0.736	0	-0.038	-0.002	-0.061
	0	*7.382*	*0.442*	*5.302*

r2	k	rat	dfq	dfa
0.415	2.24	-1.704	0.001	-0.053
	0.863	*3.468*	*0.116*	*3.099*

r2	k	dat	dfq	dfa
0.867	0	-0.026	-0.001	-0.037
	0	*11.618*	*0.455*	*7.316*

r2	k	rat	dfq	dfa
0.668	1.901	-1.446	0	-0.035
	1.578	*6.339*	*0.163*	*4.39*

Equation 5

r2	k	dat	f1/f2	dfa
0.919	0.005	-0.029	0.207	-0.024
	0.009	*15.564*	*0.817*	*4.764*

r2	k	rat	f1/f2	dfa
0.673	2.065	-1.562	0.458	-0.019
	1.673	*6.625*	*0.909*	*1.934*

r2	k	dat	f1/f2	dfa
0.736	-0.008	-0.038	-0.314	-0.064
	0.006	*7.382*	*0.442*	*4.607*

r2	k	rat	f1/f2	dfa
0.415	2.243	-1.704	0.122	-0.052
	0.872	*3.468*	*0.116*	*2.539*

r2	k	dat	f1/f2	dfa
0.867	-0.004	-0.026	-0.141	-0.038
	0.006	*11.618*	*0.455*	*6.283*

r2	k	rat	f1/f2	dfa
0.668	1.903	-1.446	0.079	-0.034
	1.593	*6.339*	*0.163*	*3.596*

Equation 6

r2	k	dat	ln(f1/f2)	dfa
0.919	0	-0.029	0.612	-0.023
	0	*15.564*	*0.817*	*4.663*

r2	k	rat	ln(f1/f2)	dfa
0.673	2.053	-1.562	1.354	-0.019
	1.65	*6.625*	*0.909*	*1.877*

r2	k	dat	ln(f1/f2)	dfa
0.736	0	-0.038	-0.929	-0.064
	0	*7.382*	*0.442*	*4.544*

r2	k	rat	ln(f1/f2)	dfa
0.415	2.24	-1.704	0.36	-0.052
	0.863	*3.468*	*0.116*	*2.496*

r2	k	dat	ln(f1/f2)	dfa
0.867	0	-0.026	-0.418	-0.038
	0	*11.618*	*0.455*	*6.193*

r2	k	rat	ln(f1/f2)	dfa
0.668	1.901	-1.446	0.235	-0.034
	1.578	*6.339*	*0.163*	*3.535*

7.11 Inner and Outer London area Modelling

The objective of this particular part of the analysis, is to identify any relationship between choice of airports made by different passenger types within the Greater London and other South East areas. This provides more detailed analysis on the choice of travel behaviour between passengers within the Greater London area. Modelling is carried out for the London area airports (LGW, LHR, LTN, STN), where data on passenger origin destination for Greater London area is obtained from CAP 610 (1991). Two relationships which involve the ratio of access distances and the difference in access distances from the specific areas to the airports are examined. The modelling process involves a simple linear relationship between the dependent and independent variables shown below.

$$\ln (P_1/P_2) = \beta_1.(\text{rat}) + \beta_0 \quad \text{and}$$

$$\ln (P_1/P_2) = \beta_1.(\text{dat}) + \beta_0$$

where

P_1	= Probability of choosing airport 1
P_2	= Probability of choosing airport 2
rat	= Ratio of access distance from areas to airports
dat	= Difference of access distance from areas to airports
β_1	= Coefficient to be determined
β_0	= Airport specific constant

The relationship takes the form of a linear equation where the dependent variable is the logarithmic ratio of passengers from different areas to the airports and the independent variable is either the ratio or difference of access distances. The access distances are measured by straight line method or "crow distances". The modelling results for the international scheduled passengers are shown by the tables in section 7.12 and for the international charter passengers by the tables in section 7.13.

7.11.1 Discussion of Results for Scheduled Passengers

It can be seen that for both ratio and difference in access distance coefficients *t* values are significant at the 99% confidence level. The constant β_0 is the highest for LHR/LTN or LTN-LHR cases followed by that of STN then by LGW. This indicates that passengers perceive LHR to be an attractive choice when comparing with LTN, STN and LGW in that order. This conforms with intuition since LHR for the London area passengers is associated with larger frequencies of flights, wider choice of fares (more airlines offering different choices) and on average better access than LTN, STN and LGW.

The values of coefficients for the independent variable are also consistent amongst the passenger types for both types of equations. The coefficient of determination r^2 values are low for cases where the sample size of passengers are extremely small. For example from some of the inner London areas there are no UK business passengers using LTN, therefore this reduces the size of the data sample since the dependent variable ln (LHR/LTN) is not divisible. The results confirm that there is consistency amongst the six passenger types when making decisions regarding choice of airports.

The modelling results for LGW, LTN and STN airports are also shown in section 7.12 for the scheduled passengers. These results show that LGW has constant β_0 value higher for LGW/LTN than for LGW/STN for all passenger types. Similar is the case for difference in access distance coefficients for LTN-LGW over STN-LGW. This is compatible with the above finding for the four airports cases. An exception to the results for both results is the foreign IT passengers. The sample size is low for this passenger type in comparison to the other passenger groups.

7.11.2 Discussion of Results for Charter Passengers

Charter modelling involves the three London area airports (LGW, LTN and STN) since data for LHR on charter passengers are not available. The modelling results are shown by the tables in section 7.13. Analysis is carried out in exactly the same way as for scheduled passengers. The r^2 and t values are small for certain passenger types for example Business and IT foreign and this is associated with small sample size of passengers. For most of the passenger types the t value is significant at the 99% confidence level. With the exception to Business and IT foreign passengers, for all other passengers the constant k is higher for LGW/STN than LGW/LTN. This is opposite to the findings for scheduled passengers. This shows that for charter passengers LTN is a more attractive choice than STN.

		Ratio of Access Distance					Difference of Access Distance					
ln (LHR/Y)		r2	β_1	β_0	$t(\beta_1)$	$t(\beta_0)$		r2	β_1	β_0	$t(\beta_1)$	$t(\beta_0)$
BUS	LHR/LGW	0.521	-1.56	2.93	7.51	17.07	LGW-LHR	0.413	0.025	1.32	6.06	13.16
	LHR/LTN	0.295	-0.99	6.93	3.37	17.89	LTN-LHR	0.321	0.025	5.68	3.58	23.33
	LHR/STN	0.542	-2.13	5.9	6.9	19.24	STN-LHR	0.58	0.037	3.36	7.43	16.7
BUS F		0.575	-1.73	3.01	8.31	17.48		0.45	0.028	1.23	6.47	11.9
		0.31	-0.84	6.13	3.4	20.11		0.313	0.02	5.17	3.45	25.35
		0.49	-1.74	5.44	5.68	17.72		0.51	0.031	3.42	6.15	17.97
IT UK		0.357	-1.31	1.54	5.38	7.72		0.249	0.02	0.22	4.15	1.93
		0.207	-0.587	4.76	2.45	13.91		0.12	0.01	4.1	1.77	19.71
		0.198	-0.927	4.57	2.81	12.73		0.262	0.02	3.44	3.38	16.98
IT F		0.027	-0.59	1.14	0.94	2.03		0.06	0.014	0.43	1.33	1.64
		0.34	-13.91	13.06	1.02	1.65		0.43	0.325	-0.92	1.22	-0.174
		0.23	-1.66	3.85	1.79	3.95		0.16	0.02	2.15	1.44	4.02
OT UK		0.556	-1.25	1.8	8.07	14.14		0.29	0.02	0.58	4.62	6.82
		0.33	-0.97	5.01	4.82	22.4		0.2	0.02	3.99	3.49	25.55
		0.36	-1.23	4.48	5.21	20.43		0.48	0.024	3	6.8	21.3
OT F		0.4	-1.1	1.87	5.91	12.21		0.19	0.014	0.81	3.51	8.58
		-0.2	-0.88	5.32	3.35	18.22		0.16	0.02	4.36	2.93	21.16
		0.35	-1.33	4.94	5.14	20.54		0.4	0.02	3.4	5.74	20.34
Total		0.627	-1.31	2.09	9.36	18.17		0.36	0.02	0.8	5.25	9.99
		0.283	-0.89	5.52	4.49	25.86		0.19	0.02	4.59	3.42	30.47
		0.53	-1.63	5.18	7.67	26.51		0.612	0.03	3.28	9.06	25.36
ln (LGW/Y)												
BUS UK	LGW/LTN	0.496	-0.98	5.43	5.16	15.48	LTN - LGW	0.488	0.02	4.18	5.08	18.66
	LGW/STN	0.636	-1.91	4.51	8.37	15.17	STN - LGW	0.57	0.03	2.26	7.25	13.39
BUS F		0.413	-0.81	4.7	4.28	13.98		0.4	0.02	3.81	4.13	17.46
		0.56	-1.67	4.24	6.68	12.72		0.52	0.03	2.34	6.18	13.38
IT UK		0.2	-0.5	4.25	2.4	10.1		0.11	0.01	3.66	1.68	12.64
		0.25	-0.91	4.31	3.26	11.16		0.19	0.01	3.25	2.75	15.64
IT F		0.19	44	-32.7	0.48	0.41		0.08	-0.63	9.3	0.3	0.81
		0.67	-1.32	3.87	3.8	8.04		0.46	0.02	2.33	2.38	6.86
OT UK		0.46	-0.92	4.47	6.35	19.76		0.22	0.013	3.43	3.64	20.74
		0.46	-1.3	4.11	6.66	17.24		0.4	0.02	2.65	5.84	20.02
OT F		0.37	-0.92	4.72	5.14	16.68		0.23	0.02	3.67	3.66	19.01
		0.39	-1.36	4.36	5.63	14.6		0.27	0.02	2.84	4.29	16.62
Total		0.47	-0.94	4.86	6.69	22.59		0.22	0.01	3.81	3.82	24.06
		0.6	-1.57	4.53	8.92	21.26		0.48	0.02	2.78	6.96	21.57
ln (LTN/STN)												
BUS UK	LTN/STN	0.21	-1.38	-0.34	2.56	0.65	STN - LTN	0.18	0.02	-1.94	2.32	6.52
BUS F		0.39	-1.66	0.3	3.61	0.64		0.27	0.03	-1.57	2.7	5.76
IT UK		0.52	-1.59	1.53	4.02	3.47		0.46	0.03	-0.52	3.6	1.94
IT F		0.36	-12.98	9.61	0.74	0.59		0.28	0.22	-3.19	0.62	2.07
OT UK		0.28	-1.37	0.78	4.24	2.42		0.25	0.02	-0.76	3.92	5.49
OT F		0.19	-1.67	0.98	3.21	1.95		0.11	0.02	-0.79	2.28	3.41
Total		0.38	-1.65	0.76	5.6	2.62		0.25	0.02	-1.03	4.12	7.79

In (LGW/Y)		Ratio of Access Distance r2	β_1	β_0	$t(\beta_1)$	$t(\beta_0)$		Difference of Access Distance r2	β_1	β_0	$t(\beta_1)$	$t(\beta_0)$
BUS UK	LGW/LTN	0.182	0.391	1.202	*1.636*	*2.062*	LTN - LGW	0.008	0.002	2.079	*0.309*	*4.358*
	LGW/STN	0.218	-0.831	3.471	*1.974*	*6.108*	STN - LGW	0.169	0.013	2.426	*1.686*	*6.421*
BUS F		0.017	0.315	1.37	*0.347*	*1.419*		0.178	-0.009	1.652	*1.233*	*5.793*
		0.377	0.208	-0.308	*1.347*	*1.142*		0.286	-0.006	-0.058	*1.123*	*0.306*
IT UK		0.553	-0.887	3.551	*7.944*	*20.737*		0.552	0.019	2.594	*7.93*	*24.919*
		0.508	-1.822	5.283	*6.818*	*17.469*		0.386	0.021	3.433	*5.318*	*19.627*
IT F		0.111	-0.322	2.433	*1.276*	*4.422*		0.087	0.009	2.085	*1.116*	*5.304*
		0	-0.004	1.841	*0.009*	*2.554*		0.019	0.005	1.826	*0.515*	*4.498*
OT UK		0.419	-1.047	4.212	*6.069*	*15.876*		0.523	0.025	3.098	*7.477*	*21.329*
		0.358	-1.592	5.503	*4.896*	*13.155*		0.415	0.026	3.659	*5.52*	*17.649*
OT F		0.101	-0.344	2.907	*1.984*	*9.697*		0.133	0.008	2.544	*2.321*	*13.802*
		0.138	-0.633	3.331	*2.192*	*8.698*		0.088	0.007	2.572	*1.702*	*11.694*
ALL		0.549	-0.879	3.616	*8.028*	*21.797*		0.617	0.02	2.675	*9.238*	*28.976*
		0.468	-1.441	4.87	*6.824*	*19.198*		0.422	0.02	3.238	*6.224*	*22.985*

In (LTN/STN)		r2	β_1	β_0	$t(\beta_1)$	$t(\beta_0)$		r2	β_1	β_0	$t(\beta_1)$	$t(\beta_0)$
BUS UK	LTN/STN	0.485	3.602	-2.361	*1.372*	*0.926*	STN - LTN	0.39	-0.042	1.45	*1.131*	*1.56*
BUS F		0.348	-0.456	-0.969	*1.034*	*1.361*		0.336	0.015	-1.45	*1.006*	*3.66*
IT UK		0.324	-1.732	2.789	*4.646*	*7.447*		0.19	0.02	0.896	*3.246*	*5.1*
IT F		0.005	-0.271	0.314	*0.157*	*0.211*		0.005	0.004	0.038	*0.163*	*0.054*
OT UK		0.289	-2.756	3.72	*4.132*	*5.51*		0.213	0.04	0.621	*3.369*	*2.063*
OT F		0.017	-0.375	0.772	*0.649*	*1.333*		0.002	-0.002	0.472	*0.242*	*1.575*
ALL		0.287	-1.729	2.44	*4.617*	*6.612*		0.177	0.019	0.576	*3.381*	*3.534*

7.14 Summary

In this chapter modelling has been carried out for three market types short haul, charter and long haul and for six passenger groups - UK and foreign business, leisure IT and leisure OT. It has been acknowledged that passengers' choice of airport and in general travel behaviour differ, depending on the factors that determine their utility function. Eighteen modelling results are produced in this study, covering the three different market types and the six passenger groups.

In total twelve combination of access time, frequency and fare variables have been tested in this research. Regression analysis carried out for regions independently and aggregate of all regions for all combination of variables. Modelling results for all three markets show that difference in access time equations are better than the ratio of access time equations. The results have been assessed based on modelling criteria used by other research findings on this subject. Mainly in order of importance the prior assumptions of signs of coefficients of explanatory variables, the *t* significance and the coefficient of determination r^2. The signs are expected to be negative and positive for access and frequency coefficients for all passengers, while for non business the fare coefficient is also expected to be negative.

The best equation from the six *difference in access time* equations is used, if necessary with dummy variables to predict the observed passenger share at airports. Most of the results show that the observed passenger shares predicted for the airports are obtained with a combination of difference in access time, logarithmic difference in frequencies and weighted differences in fares. The summary of results that produce the best observed and predicted market share for the airports for the three models have been shown and discussed in this chapter. The detailed results of the regression analysis are shown in appendix A to appendix D.

For most of the coefficients on all three markets for all passenger types, the signs are of the expected type and the *t* significance are above the 99% confidence level. There are consistencies in the access time coefficients for all three markets, in particular between the short and charter markets. The ranges of coefficients for access time vary within the limits obtained by others in airport choice. The frequency coefficients obtained for charter are more realistic than the short haul models.

Detailed analysis of airport choice between passengers for the Greater London and other South East areas have also been examined in this chapter. Modelling is carried out for international scheduled and charter passengers. The results show that there is consistency with respect to access time amongst different passenger groups from the Greater London and other South East areas in choosing airports.

The regional analysis show the magnitude of access time coefficients to be similar for the short haul and charter models, with exception to one or two passenger types. However the results show that passengers travelling on short haul market attach more importance to access time than those on the charter market. The detailed analysis for the London area passengers also reveal this phenomenon. Therefore conclusions can be drawn that passengers from other regions and those from the inner London areas perception of access time are identical.

Using the modelling coefficients derived for different passenger groups for the three markets, the implications of the noise cost on passengers choice of airports is evaluated in the next chapter.

IMPLICATION OF NOISE CHARGE AT AIRPORTS

8.1 Introduction

In the previous chapter modelling results are produced for three market types short haul, charter and long haul. This chapter evaluates the implication of the noise charges developed in chapter five on passengers choice of airports, using the modelling coefficients determined in the last chapter.

In this chapter the contribution to fares are first calculated for each of the airports by grouping aircraft by market types. By adding the contribution due to the noise charge to the fare values in the modelling, the new predicted passenger demand at airports is obtained. For comparison purposes passenger demand at airports are produced using the value of time used by the Department of Transport UK. The two results are presented and discussed towards the end of the chapter.

8.2 Calculation of Contribution to Fares for Aircraft Types by Market Segment

Some airports such as Manchester operate on short haul, charter and long haul routes using the same aircraft types. Other airports such as Heathrow use the same aircraft type to operate on short and long haul routes. Before the implication of the noise charge can be evaluated, it is necessary to identify what proportion of the same aircraft are used on short haul, long haul and where applicable charter destinations.

The derivation of the contribution to fares for aircraft types are discussed for Heathrow, Stansted and Manchester airports. The derivation of the contribution calculations for Birmingham and Luton are similar to that of Stansted, since aircraft operating at these airports are either on the short haul or charter or both markets. The contribution to fares calculation for Gatwick is similar to that of Manchester. Both Manchester and Gatwick operate some aircraft which are of the same type on all three markets. Therefore for Birmingham, Luton and Gatwick airports the tables of the contribution to fares and the aircraft types operating by market segment are presented only.

8.2.1 Contribution to Fares for Heathrow

The aircraft types that operate both on the short and long haul routes at Heathrow are shown in table 8.1 Data on aircraft types flown to particular destinations from different airports are obtained from ICAO Digest of Statistics Traffic by Flight Stage (1992).

Heathrow Aircraft Types
Short and Long Haul
B 767 A 310 B 757 A 320

Table 8.1 Aircraft used on both Short and Long Haul Routes

Tables 8.2 and 8.3 show the derivation of the contribution to fares calculations for the short and long haul markets at Heathrow airport. For the aircraft types that operate on both markets, the total annual movements are divided in the proportion of frequencies served on those two markets. Data on the proportion of frequencies on the short and long haul routes for Heathrow are obtained from the airport authorities statistics department. The load factors used are the average of the six routes for the short haul and the average of the three routes for the long haul. Therefore from tables 8.2 and 8.3 the aircraft types that operate on short and long haul routes can be identified with the contribution to fares due to the noise charge. The procedure of calculating the contribution to fares for all other airports are similar to that of Heathrow as shown by tables 8.2 and 8.3.

As an example B767 serves both the short and long haul markets from Heathrow as shown by table 8.1. Referring to table 8.2, the noise cost calculated (from chapter five) for a B767 is £194 with a seating capacity of 220. The load factors served for the short haul is 60% making the effective number of passengers carried by a B767 to be 132 (60% of 220). Therefore the cost per passenger due to the noise charge is £1.47, that is £194/132. The total annual movement by a B767 from Heathrow is 30881 from which the movement to the short haul market is 22852. The total annual movement is divided in the proportion of frequencies of service to the short and long haul markets. Thus after subtracting the short haul movements from the total annual movements leaves the movements served for the long haul market, that is 8029 (30881-22852) as shown by table 8.3. The contribution to fares for the B767 is then obtained by multiplying the cost per passenger with the figure for the movement for short haul and dividing by the total number of movements by all aircraft on the short haul market (£1.47 x 22852) / 286120. Similarly calculations are carried out for all other aircraft serving the short haul market, and the summation of all the figures for the various aircraft type represent the contribution due to the noise charge. Therefore for aircraft types that operate on the short haul market for Heathrow it is £3.40.

Heathrow Short Haul							
Aircraft Type	Noise Cost £	Seats	Load Factor 60%	Cost/Pax £	Movements Annual	Movements Sh. Haul	Contribution £
B707/720	4636	189	113	40.89	776	776	0.11
B727	316	189	113	2.78	5571	5571	0.05
BAe 146	176	80	48	3.66	1593	1593	0.02
B767	194	220	132	1.47	30881	22852	0.12
A310	194	280	168	1.16	20482	15157	0.06
F 27	166	44	26	6.29	2731	2731	0.06
B757	170	239	143	1.18	56297	41660	0.17
TU 134	316	110	66	4.78	271	271	0.00
B737	331	130	78	4.24	114724	114724	1.70
BAe 1-11	331	89	53	6.19	279	279	0.01
DC9/MD 80	350	115	69	5.07	50018	50018	0.89
F 28	190	85	51	3.72	4102	4102	0.05
F 100	162	107	64	2.52	947	947	0.01
A320	158	179	107	1.47	32400	23976	0.12
HERALD	160	40	24	6.66	195	195	0.00
F 50	160	58	35	4.60	1269	1269	0.02
Total						286120	3.40

Table 8.2 Contribution to Fares Calculation for Short Haul

Heathrow Long Haul							
Aircraft Type	Noise Cost £	Seats	Load Factor 72%	Cost/Pax £	Movements Annual	Movements L. Haul	Contribution £
CONCORD	22223	132	92	240.51	1775	1775	4.54
B747	864	440	308	2.81	42058	42058	1.26
ILYUSHIN	686	350	245	2.80	466	466	0.01
DC10	437	380	266	1.64	3107	3107	0.05
MD 11	394	405	284	1.39	835	835	0.01
TRISTAR	276	333	233	1.18	1107	1107	0.01
TU 154	207	180	126	1.64	2025	2025	0.04
B767	194	220	154	1.26	30881	8029	0.11
A310	194	280	196	0.99	20482	5325	0.06
A300	221	345	242	0.91	6199	6199	0.06
B757	170	239	167	1.01	56297	14637	0.16
A320	158	179	125	1.26	32400	8424	0.11
Total						93987	6.42

Table 8.3 Contribution to Fares Calculation for Long Haul

8.2.2 Contribution to Fares for Manchester

The aircraft types that operate on the short haul and charter, short haul, long haul and charter from Manchester are shown by table 8.4. The percentage of frequency of services on charter and short haul routes for Manchester airport are obtained from Civil Aviation Policy (CAP) 614 and the frequency on the long haul market is determined previously in the last chapter. Aircraft that operate on the short and long haul routes are divided in the proportion of frequency on these markets. The aircraft that operate on all three markets are divided in the proportion of frequencies on all three markets. In calculating the number of movements for aircraft types for different markets, the total annual movement is divided in the same proportion as the frequency of services.

Manchester Aircraft Types	
Short Haul and Charter	Short, Long and Charter
BAe 1-11	B 727
DC9/MD8	B 767
	B 757
	B 737
	A 320

Table 8.4 Same Aircraft Type Operating on Different Markets

Tables 8.5 show the contribution to fare calculations for short haul, long haul and the charter market from Manchester airport. For the load factors the average over the chosen routes are taken. The calculations for Gatwick are identical to that of Manchester. The aircraft types that operate on different markets from Gatwick are shown by table 8.6. The contribution calculations for Gatwick for the short haul, long haul and the charter market are shown by table 8.7.

Manchester Airport Short Haul		Long Haul		Charter	
Aircraft Type	Contribution £	Aircraft Type	Contribution £	Aircraft Type	Contribution £
B727	0.03	B747	0.22	BAe 1-11	0.40
BAe 146	0.05	L TRISTAR	0.06	DC9/MD8	0.21
B767	0.07	A310	0.04	B727	0.02
B757	0.13	A300	0.03	B767	0.05
B737	1.03	DC 8	0.02	B757	0.10
BAe 1-11	0.89	B727	0.02	B737	0.77
DC9/MD 8	0.48	B767	0.06	A320	0.01
F 28	0.01	B757	0.11		
A320	0.02	B737	0.83		
		A 320	0.01		
Total	2.70		1.39		1.56

Table 8.5 Contribution to Fares for Manchester Airport

Gatwick Aircraft Types	
Short Haul and Charter	Short, Long and Charter
B 727	B 757
F 27	B 767
B 737	A 320
BAe 1-11	
DC9/MD8	
F 28	
F 100	

Table 8.6 Same Aircraft Type Operating on Different Markets

Gatwick Airport Short Haul		Long Haul		Charter	
Aircraft Type	Contribution £	Aircraft Type	Contribution £	Aircraft Type	Contribution £
B727	0.01	B747	0.19	B727	0.02
B757	0.01	B707/720	0.15	F 27	0.03
BAe 146	0.07	DC 10	0.05	B737	0.45
B767	0.01	L TRISTAR	0.03	BAe 1-11	0.09
F 27	0.02	A300	0.01	DC9/MD 8	0.06
EMB BAND	0.02	A310	0.01	F 28	0.01
B737	0.28	TU 154	0.00	F 100	0.00
BAe 1-11	0.06	B757	0.01		
DC9/MD 8	0.04	B767	0.01		
F 28	0.00	A320	0.00		
F 100	0.00				
A320	0.00				
SAAB 340	0.04				
HERALD	0.01				
SHORTS	0.09				
ATR 42	0.06				
Total	0.71		0.47		0.65

Table 8.7 Contribution to Fares at Gatwick for Aircraft by Different Markets

8.2.3 Contribution to Fares for Stansted

Aircraft types that operate on both the short and charter routes from Stansted are shown by table 8.8. The percentage of movements on short and charter routes for Stansted, Luton and Birmingham are obtained by dividing the total number of passengers carried on each of these markets. The percentage of passengers are used for these airports instead of percentage of frequencies, since CAP 614 gives the total frequency on scheduled services from airports and does not provide individual figures on frequency for short and long haul routes.

Stansted Aircraft Types
Short Haul and Charter
BAe 146
F 27
B 737
BAe 1-11
F 100

Table 8.8 Aircraft on Short Haul and Charter Market

Tables 8.9 show the contribution to fare calculations for short haul and charter markets for Stansted. Based on similar principles the calculations for Luton and Birmingham are also derived. Tables 8.10 and 8.11 show the aircraft types that operate on short haul and charter markets from Luton and Birmingham airports.

Stansted Airport			
Short Haul		Charter	
Aircraft Type	Contribution £	Aircraft Type	Contribution £
B747	0.00	BAe 146	0.02
B707/720	0.02	F 27	0.01
DC10	0.00	B737	0.00
BAe 146	0.01	BAe 1-11	0.07
B767	0.00	F 100	0.03
BAe 748	0.00		
F 27	0.01		
B757	0.00		
EMB BAND	0.01		
EMB BRASI	0.01		
B737	0.00		
BAe 1-11	0.05		
DC9/MD 8	0.01		
F 100	0.02		
F 50	0.00		
ATR 42	0.00		
SHORTS	0.00		
SAAB 340	0.00		
Total	0.15		0.13

Table 8.9 Contribution to Fares at Stansted

Luton Aircraft Types	
Short Haul and Charter	Charter
BAe 146	B 767
BAe ATP	A 310
F 27	A 300
B 737	B 757
BAe 1-11	DC 9
SHORT	A 320
SAAB 340	HERALD
EMB BAND	L. ELECTRA

Table 8.10 Aircraft Operating on Short Haul and Charter Markets from Luton

Birmingham Aircraft Types
Short Haul and Charter
BAe ATP F 27 B 737 BAe 1-11 DC9/MD8 F 28 BAe JET F 50

Table 8.11 Aircraft on Short Haul and Charter Markets from Birmingham

Luton Airport Short Haul		Charter	
Aircraft Type	Contribution £	Aircraft Type	Contribution £
BAe 146	0.51	B767	0.08
BAe ATP	0.11	A310	0.01
F 27	0.07	A300	0.02
B737	3.00	B757	0.12
BAe 1-11	1.01	DC-9	0.16
SHORTS	0.56	A320	0.03
SAAB 340	0.07	HERALD	0.05
EMB BAND	0.13	L ELECTRA	0.02
		BAe 146	0.29
		BAe ATP	0.06
		F 27	0.04
		B737	1.71
		BAe 1-11	0.58
		SHORTS	0.32
		SAAB 340	0.04
		EMB BAND	0.07
Total	5.45		3.60

Table 8.12 contribution to Fares for Aircraft by Different Markets for Luton

A summary of the contribution to fares for each of the markets from the different airports are shown by table 8.14. The noise landing charge was discussed in chapter five where it is acknowledged, that airports with a large number of houses affected by aircraft noise are associated with high noise landing charges. Therefore at Stansted the noise cost for aircraft movements are very low, since the number of houses affected by aircraft noise are the lowest at Stansted compared to the other airports.

Birmingham Airport			
Short Haul		Charter	
Aircraft Type	Contribution £	Aircraft Type	Contribution £
B727	0.16	BAe ATP	0.25
BAe 146	0.08	F 27	0.33
B767	0.04	B737	0.90
A310	0.01	BAe 1-11	4.49
BAe ATP	0.28	DC9/MD 8	0.92
F 27	0.37	F 28	0.05
B757	0.06	BAe JET	0.39
B737	1.01	F 50	0.23
BAe 1-11	5.06		
DC9/MD 8	1.04		
F 28	0.06		
A320	0.01		
HERALD	0.08		
SHORTS	0.13		
BAe JET	0.44		
SAAB 340	0.07		
F 50	0.26		
DASH 7	0.16		
DASH 8	0.03		
L ELECTRA	0.02		
Total	9.37		7.56

Table 8.13 Contribution to Fares at Birmingham for Aircraft by Different Markets

For the calculation of contribution to fares at airports, specific aircraft characteristics are important factors. For example the contributions are higher at airports such as Birmingham, where for certain aircraft BAe 1-11 and B737 the noise cost is the highest, the load factor is lowest on that market compared to other airports and the number of movements are the highest in the group. This implies that the extra cost of noise is distributed amongst fewer number of passengers, causing the contribution per passenger to be high.

Contribution (£)			
	Short Haul	Long Haul	Charter
LGW	0.71	0.47	0.65
LHR	3.40	6.42	
LTN	5.45		3.60
STN	0.15		0.13
BHX	9.37		7.56
MAN	2.70	1.39	1.56

Table 8.14 Summary of the Contributions at Airports

The contributions at LGW, STN and possibly MAN for the short haul market are low. Since a large proportion of passengers on the short haul market are of business type and the fare being the least important factor for airport choice, this will minimise the significance of the noise cost at these airports. On the long haul market the fare increase at LHR should have significant implications. In airport choice the fare is the most important factor for leisure passengers, and the percentage of leisure passengers on the long haul routes tend to dominate over the business passengers. For the charter market with the exception to BHX, fare increases at other airports may be considered insignificant

8.3 Implications of the Noise Charge

By adding the contribution to fares to the fare variables the new passenger demand is forecasted for the airports by the models developed in the previous chapter. The implication of the noise cost on passengers' choice of airports are shown in table 8.15. The positive figures indicate a gain at airports while a negative figure means a loss at those airports.

For the short haul LGW, STN gain passengers while LHR, LTN and MAN lose passengers. LHR, LTN and MAN have higher contributions than LGW and STN, this explains why passengers transfer their use of LHR, LTN and MAN to LGW and STN airports. BHX despite having the highest contribution in the whole group gains passengers, however the percentage gained is the smallest in the group. The similarity in LGW and LHR results indicate that most of the passengers gained by LGW can be assumed to be from LHR. Overall passenger numbers either gained or lost at LTN, STN, BHX and MAN fall within ranges of a maximum of 11 percent at LTN and a minimum of 0.6 percent at MAN. However the figures predicted for LGW and LHR are high considering the characteristics of passengers on the short haul market (i.e., fares being the least important factor for airport choice).

For the charter market LTN and BHX have the highest contributions in the group, however passengers are gained at these airports. This is explained by the fact that in modelling for UK leisure IT and OT passengers, the coefficient of the fare variables are taken as positive instead of negative. Although the fare coefficients for foreign leisure IT and OT are negative, the passenger numbers for UK leisure IT and OT are almost six to ten times as much as the foreign leisure IT and OT for all the airports. Therefore a high number of passengers with a positive fare coefficient for UK leisure IT and OT dominate the predicted results for the airports with a low number of foreign leisure IT and OT passengers and a negative fare coefficient. MAN loses the most passengers compared to LGW and STN since MAN has a higher contribution to fares to that of LGW and STN. With the exception of BHX, the absolute number of passengers changing airports due to the noise cost can be argued to be of the expected order.

(000's)	LGW	LHR	LTN	STN	BHX	MAN
Short Haul	1414.85	-1409.52	-37.95	37.77	10.45	-15.60
(000's)	LGW		LTN	STN	BHX	MAN
Charter	-38.77		12.71	-5.73	75.00	-43.22
(000's)	LGW	LHR				MAN
Long Haul	1188.95	-1274.85				85.90

Table 8.15 Implication of the Noise Charge at Airports

For the long haul modelling LGW and MAN gain passengers, this is expected since the contributions for LHR is far greater than that of LGW and MAN. As the results demonstrate it is reasonable to expect that LGW should gain a large percentage of passengers from LHR than MAN, since fare increase at LGW is lower compared to that of LHR or MAN.

8.4 Implications using Department of Transport Value of Time

The magnitude of passengers changing airports particularly at LGW and LHR for the short and long haul markets, indicate that some doubts can be cast on the fare coefficients found in the models in this study. A high number of passengers changing airports means that results determined in this study are extremely sensitive to the fare coefficients. Passengers both business and leisure UK or foreign receive discounts on fares and therefore the fares used in the research may not represent the fares actually paid. As acknowledged by Brooke et al (1994) exact fare details are difficult to obtain, therefore research on airport choice modelling usually involves taking fare details from the ABC World Airways Guide fares.

In addition ABC World Airways Guide does not provide fare details for the London area airports (LGW, LHR, LTN and STN) by airport categorisation. For this reason just one fare value was used for the London airports for the short haul modelling. Therefore using the same fare for four airports out of the six in total for the short haul model, must result in the loss of accuracy for the fare coefficients. This loss of accuracy is reflected in the models by the high number of passengers changing airports, when it can be argued that the fare increases due to the noise cost is small. Similarly for the long haul model the same fare value was used for LGW and LHR, therefore this explains the sensitivity of the fare coefficients.

For comparison purposes the value of time used by UK Department of Transport for air transport passengers are used in this section. The values of access time for business and leisure by UK and foreign passengers from Civil Aviation Policy (CAP) 570 are used. The values used are in hours 1987 prices in 1991 values, being £30.91 for UK and £35.51 for foreign business and £5.18 for all leisure passengers. The access time coefficient β_1 (page 122) is divided by the value of time used by the Department of Transport to obtain the new coefficient β_3. This new coefficient is used for the fare variable to produce the new passenger demands at airports using the other parameters estimated in this study. The new passenger demand at airports using Department of Transport value of time are shown by table 8.16.

The results for the short and long haul model indicate substantially higher figures at LGW and LHR. Results at airports for the charter model fall within the ranges produced in this study with the exception of STN and BHX. Overall the results show that the average value of time for all passengers' used by Department of Transport, is lower than that obtained in this study. This explains why higher forecasts occurs at certain airports. The Department of Transport disaggregate passenger time values by UK and foreign business and leisure. However in this study leisure is further divided by IT and OT, having different access time coefficients in all the three models. Therefore one time value for both UK and foreign for leisure passengers is used in the two different models.

(000's)	LGW	LHR	LTN	STN	BHX	MAN
Short Haul	2419.07	-2403.46	-48.14	40.90	-2.53	-5.85
(000's)	LGW		LTN	STN	BHX	MAN
Charter	11.34		-6.60	-98.01	75.41	17.86
(000's)	LGW	LHR				MAN
Long Haul	3407.01	-3476.58				69.57

Table 8.16 Passenger Shares using Department of Transport Value of Time

For the short haul market LHR, LTN, BHX and MAN lose passengers while LGW and STN gain passengers. The difference is that BHX lose passengers while previously it gained passengers. The magnitude of passengers lost at LHR and gained at LGW are almost twice that of the results obtained in this study. The difference for the charter results are more significant than that of the short haul results. LGW and MAN gains passengers while previously both these airports lost passengers. The long haul results remain the same in pattern except LGW gains more in passenger share, while LHR loses almost twice as much passenger share.

8.5 Positive Feedback Effect

For the next part of the analysis in this chapter, the effects of the new passenger demand created at certain airports due to the positive feedback effect are examined. For example for both short and long haul the model results demonstrate, a large number of passengers could transfer to LGW mainly from LHR. Additional flights would be required at LGW to cater for this new demand of passengers. Simultaneously a further extra demand of passengers would be created due to the introduction of additional frequencies of flights. This process is likely to carry on until an equilibrium is reached where, additional frequencies will not attract any extra demand and vice versa. As Alamdari and Black (1992) suggest, there is a two-way influence between demand and frequency.

This is also in agreement with the well known "S curve" effect associated with demand and frequency (de Neufville, 1976). The logic behind the "S curve" is that an airport will continue to attract disproportionately a higher passenger share until a critical frequency level is reached. Further increase in frequency will not attract passengers in the same proportion i.e., leading to a diminishing marginal effect.

The Multiple Airport Demand Allocation Model or MADAM (National Capital Regional Transportation Board, 1985), is one of the limited studies on this subject attempts to simulate the positive feedback effect. MADAM assigns flights and passengers to airports in an iterative manner. More flights are assigned to airports with more traffic and more traffic is assigned to airports with more flights. Hansen (1994) models this positive feedback effect for a multiple airport system, using data on the San Francisco Bay Area. Frequencies and market shares for the airports are iterated until an equilibrium is reached.

There are two issues involved in modelling the positive feedback effect. First the response of airlines in terms of aircraft choice when additional passengers transfer to certain airports. Secondly response of passengers to the new services offered by the airlines. It can be seen that to examine the positive feedback effect further models have to be developed in addressing the above two mentioned issues. The frequency coefficients particularly for the short haul model found in this study are high. The difference between the new passenger demand at airports predicted by the models are very large i.e., for the short haul between LGW and BHX approximately over 1.4

million. This high passenger number converted into frequencies cannot be iterated to give sensible results.

8.6 Summary

The aircraft types that are used for different markets are identified in this chapter for all the airports. Based on either the proportion of frequencies or the number of passengers carried to the respective markets the contributions to fares are calculated. The contributions represent the cost of noise charge developed in this study for the various aircraft types. The contributions are then added to the existing fares for each of the airports to determine the implications on passenger demand.

With the exception of BHX for the short haul and the charter results, the new demand does indicate that higher the noise charge at a particular airport, a certain percentage of passengers will take advantage of airports where the charges are less. The results also show that the magnitude of passengers on the long haul market are more affected than the corresponding passengers at those airports for the short haul market. Passengers on the short haul market are less concerned with fare than on the long haul routes. This conforms with the observation that a high proportion of passengers on the short haul market are of business type, to whom the fare is of least concern in the utility function.

The sensitivity of the implications of the noise charge determined in this study have depended highly on the value of the fare coefficients (β_3). The values of the other parameters are kept constant in order to evaluate the implications of the noise charge in the form of higher fares. This indicates the importance and perhaps the dangers of relying on the single fare coefficients, depending on their accuracy can significantly influence the results of the implications of the noise charge. The conclusions of the thesis and the possible areas of further research are discussed in the next chapter.

CONCLUSIONS

9.1 Introduction

The results of the research objectives are discussed in this chapter. The findings of each of the chapters are discussed in the order of study. An outline of the problem which lead to the area of study is first reviewed. After discussion of the results by chapters, some suggestions are made regarding areas of further study.

Airport activities cause some environmental pollution mainly in the form of noise, emissions and fuel efficiency, congestion, waste of energy, water and materials. All of these different forms of pollution factors some more than others, have received the attention of the air transport industry and the users of air transport. Of all the pollutants, aircraft noise is consistently ranked as the primary one (Airport Support, 1988). Comments such as,

"aircraft noise continues to be a major constraint on the development of civil aviation. Airport expansion and construction are severely limited, airport operations are being increasingly restricted due to public opposition to aircraft noise"

are common amongst air transport planners. In view of all the long term forecasts produced in recent years, indicating that passenger traffic World-wide will double within the next 10-15 years, ICAO is considering the introduction of a more severe restricted form of certification standards in order to address the aircraft noise issue (Avmark, 1995). Analysts' point out this would be detrimental to the air transport industry.

All these factors indicate that a noise management strategy is required that balances the needs of the air transport industry, the public who use it and the people who are affected by the pollution. This study demonstrates that in addition to the regulatory standards, whether set by international organisations or independently adopted by airports, a pollution charge in the form of a noise landing charge could be used as a mechanism for noise management. Airports could further deter the use of noisy aircraft by airlines while the extra revenue generated by the noise charge could be used for financing of noise mitigation.

9.2 Review of Chapters Two, Three and Four

In chapter two, three and four subject areas such as; the measurement of aircraft noise units; methods of airport noise control and the "Polluter Pays Principle" were discussed. There is no common unit used to measure aircraft noise. Each country within Europe and the United States use their own noise indices, however ICAO uses EPNdB for Noise Certification purposes. There are two distinct elements involved in developing units for the measurement of aircraft noise. The technicality of measuring energy transference and associating that with human perception and attitude formation. This has led to the development of the many units that are used to measure aircraft noise. In the United Kingdom the Noise Number Index (NNI) has been widely used since its development, and has now been replaced by the Equivalent Continuous Sound Level (L_{eq}).

No evidence has been found which relate health effects to noise with the definition of health effects adopted in this study. The most recent UK Department of Transport research on aircraft noise and sleep disturbance, indicate that individual sensitivity, certain level of aircraft noise, gender, time of night are factors that affect sleep disturbance. The study concluded that individual rates of sleep disturbance varies markedly, after statistically controlling for the effects of aircraft noise, gender and time of night, the 2-3% most sensitive individuals are disturbed over 60% more than the average.

Noise abatement, control and exposure strategies vary from country to country, within a country and from airport to airport (Levesque et al, 1990). As an illustration of the diversity of the problem, approximately four hundred airports in the USA alone have adopted noise control strategies that fall into thirty seven categories (Cline, 1986).

Aircraft noise reduction at source is mainly carried out by using noise emission standards laid down by International Civil Aviation Organisation (ICAO). The other important measures adopted by airports are night curfews, Operational Noise Abatement Procedures (NAP), Noise Preferential Runways (NPR), Minimum Noise Routings (MNR), Slots and Capacities and Land Use Regulations. All these different types of noise control methods fall into the category of regulatory measures. In chapters three and four the advantages and disadvantages associated with regulatory measures to control airport noise have been discussed.

The noise landing charge developed in this study has been based on the concept of the "Polluter Pays Principle." Amongst various mechanisms of the Polluter Pays Principle the charge approach, also referred to as the economic instrument is recommended by environmental economists. It is acknowledged that the economic instrument can be used to complement the direct regulatory approach to abate airport noise.

The noise charges when set at an appropriate level can provide a lasting inducement for polluters to abate noise. OECD (1980) and others argue it enables noise to be abated at minimum cost to the community. The noise charges can have both an incentive and financing function. The charge would be an incentive up to the level where the marginal cost of noise abatement equals the unit rate of charge. From three different types of noise charges the damage related one is adopted in this study, as it is identified with the Polluter Pays Principle. The damage related charge has been identified to reflect the social cost of aircraft noise.

From the two methods of noise pollution valuation in monetary terms, the hedonic approach has been used for the development of the noise landing charge. Although there are a few criticisms of the hedonic approach, it can be used as a reliable method for noise valuation provided as Pearce and Markandya (1980) suggest the depreciation rate to be unity for an unit increase in noise level.

9.3 The Noise Landing Charge

The social cost of noise for take-off and approach are calculated separately for each of the airports. This reflects a more accurate assessment of evaluating the social cost of noise. By calculating the change in NNI as a result of a flyover of a particular aircraft type, the social cost is determined knowing the value of houses affected in the noise contour regions.

In this study social cost of noise is calculated for six of the major airports in England. The present landing charge based on either maximum take-off weight (MTOW), seating capacity and time use of airport runway, is added to the social cost of noise for each aircraft type to form the noise landing charge. The noise landing charge for night time operations is calculated based on the assumption that the weighting given to night time flights is ten times as much as day time flights.

The social cost of aircraft noise at an airport is a function of reference noise level, total number of aircraft movements, the price and number of houses in the affected region and the depreciation rate of house values with increase in noise level. Reference noise levels and the change in NNI for individual aircraft are related with the total number of movements. The higher the number of movements at an airport the less is the change in NNI. Stansted, Luton and Birmingham have the lowest number of total movements compared to the other airports, therefore change in NNI at these airports are the highest.

Despite having a high value for change in NNI the social cost of noise is the lowest at Stansted. This is because at Stansted the number of houses affected by aircraft noise are extremely low compared to the other airports. Although the change in NNI at Gatwick is similar to that of Manchester, the number of houses affected at Gatwick is almost half to that of Manchester. This is partially why at Manchester the cost of noise is higher than at Gatwick.

The social cost of noise is the highest at Heathrow for take-off and approach. This is due to the high number of houses in the noise affected areas and the value of houses are the highest compared to regions of other airports. The change in NNI for an aircraft flyover at Heathrow for both take-off and approach are low, since aircraft movements are the highest at this airport. For an average aircraft movement the social cost of noise at Birmingham, Manchester and Luton lie in the middle, in between the highest at Heathrow and the lowest at Gatwick and Stansted airports.

9.4 Implications of the Noise Charge

To predict more accurately the implication of the noise charge on passenger demand at airports, two assumptions regarding the application of the noise landing charge have been made. It is assumed that airlines pass on the full cost of noise to passengers and secondly airlines do not change aircraft type in order to avoid the high noise landing charges.

Disaggregation of passengers in airport choice modelling produces more useful results. Data in disaggregated form by CAA's origin destination surveys are used to develop models for different passenger types. To obtain further accuracy modelling are carried out for different market types which is analogous to CAA's 1993 and 1990 modelling. Passengers on the short, charter and long haul markets are affected differently since the market characteristics are different.

Models are developed for six passenger types business, leisure inclusive tours, leisure other, UK and foreign based for the short haul, charter and long haul markets. The model used is of the logit type with utility that includes access cost, frequency and fares. These three variables are acknowledged to be the most important components of the utility function in modelling passengers' choice of airports.

Eighteen modelling results are produced for three market types and for the six passenger groups. In total twelve combination of access time, frequency and fare variables have been tested. Regression analysis carried out for the nine regions independently and the aggregate of all regions for all combination of variables for all markets, show that *difference in access time* equations are better than the *ratio of access time* equations. Most of the results show that the best observed and predicted passenger share at airports are obtained with a combination of difference in access time, logarithmic difference in frequencies and weighted differences in fares.

The results have been assessed in order of importance the prior assumptions of signs of coefficients of explanatory variables, the *t* significance and the coefficient of determination r^2. The signs are expected to be negative and positive for access and frequency coefficients for all passengers, while for non business the fare coefficient is also expected to be negative.

The signs are of the expected type and the *t* significance are above the 99% confidence level for most of the coefficients on all three markets for all passenger types. There are consistencies in the access time coefficients for all three markets, particularly between the short and charter markets. The ranges of coefficients for access time vary within the limits obtained by others in airport choice. The frequency coefficients obtained for charter are more realistic than the short haul models.

Analysis of airport choice for international scheduled and charter passengers for the Greater London and other South East areas show that there is consistency in access time amongst different passenger groups in choosing airports. The magnitude of access time coefficients for the regions are similar for the short haul and charter models, with the exception of one or two passenger types. However the results show that passengers travelling on short haul attach more importance to access time than those on the charter destinations. Detailed analysis for the London area passengers also reveal this phenomenon. Therefore it can be concluded that passengers from other regions and those from the inner London areas response to access time differences are identical.

For the short haul, passengers either gained or lost at LTN, STN, BHX and MAN fall within ranges of a maximum of 11 percent at LTN and a minimum of 0.6 percent at MAN. Figures predicted for LGW and LHR are high considering that fare is the least important factor for airport choice for passengers on the short haul market. The similarity in LGW and LHR results indicate that most of the passengers gained by LGW transfer from LHR.

For the charter market the implication of the noise charge is assessed with the coefficient of the fare variables as positive instead of negative for UK leisure IT and OT passengers. This is the primary reason why despite having the highest fares at BHX and LTN passengers are gained at these airports. However with the exception of BHX, the absolute number of passengers changing airports due to the noise cost can be said to be compatible with expectation. For the long haul, passengers transferring use of airport from LHR to LGW and MAN are high.

The number of passengers predicted to change airports particularly at LGW and LHR for the short and long haul markets, is dependent on the sensitivity of the fare coefficients found in this study. A high number of passengers changing airports means that the fare coefficients determined in this study are subject to doubt.

Brooke et al (1994) amongst others acknowledge that exact fare details are difficult to obtain, since passengers both business and leisure UK or foreign receive discounts on fares. Studies on airport choice modelling usually involves taking fare details from the ABC World Airways Guide. However, the ABC Guide provides the fare details for the London area airports (LGW, LHR, LTN and STN) as a single value. Therefore using a single fare for the London airports results in the loss of accuracy for the fare coefficients, which to some extent is reflected by the high number of passengers changing airports.

Implication of the noise charge using value of time used by UK Department of Transport, show substantially higher number of passengers changing airports at LGW and LHR for the short and long haul models. The results show that the average value of time for all passengers' used by Department of Transport, is lower than that found in this study. The Department of Transport disaggregate passenger time values by UK and foreign business and leisure. In this study leisure is divided by IT and OT having different access time coefficients in all the three models, therefore one time value for both UK and foreign for leisure passengers is used in two different models.

9.5 Areas of Further Research

There are two main areas of research that have been examined in this study. First the context of the noise problem was identified and the methods that are used for noise control purposes reviewed. It has been pointed out that the "Polluter Pays Principle" is likely to become a more acceptable form of charging mechanism, not only for noise management but for other types of pollution such as emissions. The methodology used for valuing the cost of pollution in this study has been through the hedonic pricing. A depreciation rate of one percent decrease in house values for an unit increase in noise has been used. For further research this issue can be examined by actually measuring the depreciation rate for the airports selected in this study.

A noise landing charge has been developed for six of the major airports in England. Modelling has been carried out for the selected airports to examine the implication of the noise charges. Noise landing charges could be developed for the major airports in Scotland such as Edinburgh and Glasgow, and modelling can be carried out for these airports. Modelling for the major airports in the United Kingdom may reveal further clarification to the understanding of the subject.

There are a limited number of studies on the subject of positive feedback. This area needs further examination particularly for airports that attract a significant number of passengers from other airports. To do this additional research areas are identified such as, the response of airlines in terms of aircraft choice when additional passengers transfer to certain airports and response of passengers' choice of aircraft to the new services offered by the airlines. The evaluation of the benefits associated with the introduction of a noise landing charge of this type can also be an area of further research.

9.6 Application of The Noise Landing Charge

The application of the current landing charges at airports involve the monitoring of noise levels of aircraft. For example at Manchester Airport, 50% of the runway charge is levied if 100 PNdB are exceeded at night hours and 110 PNdB at day hours. At Heathrow 35% of the Standard charge is levied for aircraft not meeting ICAO Annex 16 Chapter 2 noise levels. Therefore the application of the noise landing charge developed in this study can be used in the same context as the current noise landing charges. The application of the "Polluter Pays Principle" landing charge requires no further monitoring than that of the other noise landing charges.

As with any noise management strategies, airport specific characteristics have to be considered before the application of the noise landing charges. At London Luton Airport the surcharge goes up incrementally i.e., for night time operations noise levels of 103-106 PNdB 150% of the surcharge is applied, between 107-110 PNdB 250% and above 110 PNdB 300% surcharge. At Manchester as mentioned above a fixed penalising method is used. The two example illustrate the differences in strategy adopted at the two airports to manage noise levels. Although a night noise landing charge has been developed in this study, a maximum noise level has to be established. In the absence of a maximum allowable noise level, the "Polluter Pays Principle" would be used in the context of a right to pollute.

Before the implementation of the noise charge several practical implications of such a policy has to be considered. An airport has a multiple relationship with a number of parties who may directly or indirectly be affected by a noise management strategy. They include:

- The central government authority, in the case of UK the Civil Aviation Authority (CAA)

- Airport owners (financiers)

- Local authorities

- Airlines

- Air transport passengers and freight forwarders

- Residents of local communities around the airports.

The implication of the noise charge and it's impact to the above mentioned bodies have to be fully evaluated before introducing a system of charges. For the airport to be successful, the relationship of the airport with any of the above bodies are vital. Therefore the multiple effect of a system of charges on each of the bodies have to be investigated.

For example in the UK generally the CAA oversee the safety requirements of air transport, therefore airport management would have to ensure that the charging policy does not violate any safety requirements of airport operations. The advantages of noise charges and the drawbacks of the regulatory system to manage noise have been discussed in chapter four. In the context of the airports studied for this research, for noise charges to be approved the airports would have to ensure that the application of this charging policy is not discriminatory.

There are three main areas which need to be evaluated for the application of the noise charge developed in this research. The legal aspects associated with the noise charge, the technical and the administrative. The revenue collected by airports due to the noise charge can provide funds for local noise abatement programmes such as sound proofing of houses, schools and hospitals. Purchasing of land for buffer zones and relocation of residents, payment of compensation grants, acquisition of noise easements are some of the other ways of redistributing the funds collected by using the noise charges. These methods have been practised by various airports in Europe and in the US. A substantial legal considerations are required and needed to be investigated in redistributing the funds in order to avoid litigation.

The technical and administrative aspects of the noise charge are mainly concerned with monitoring the level of noise and charging accordingly. At present airports monitor the level of noise made by aircraft to ensure that the maximum allowable noise levels are not exceeded. Computer printouts are used on a daily basis identifying the airline, aircraft type, flight number and the noise level of each operation. The noise charging methodology developed in this study shall not require additional monitoring equipments. The computer printouts can be easily extended providing the noise charge associated with the aircraft movement. Noise charge in this study has been developed by aircraft type basis and the noise levels made. This type of charging has been identified to be easy to administer (Nierenberg, 1978).

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Appendices

APPENDIX A

LEISURE IT PAX UK SHORT HAUL MODEL

__Difference in Access Time__

Equation 1

	r2	k	dat	dfq	wdfe
EA	0.263	0.926	-0.006	0.011	-0.049
		0.897	*0.899*	*1.751*	*0.761*
EM	0.358	-0.363	0.006	0.012	-0.008
		0.398	*0.988*	*1.878*	*0.101*
GL	0.379	0.996	-0.003	0.016	-0.092
		0.803	*0.211*	*1.904*	*1.106*
N	0.836	-0.305	0.036	0.026	0.156
		0.272	*5.614*	*3.622*	*2.251*
NW	0.356	0.131	-0.001	0.017	-0.031
		0.114	*-0.14*	*2.402*	*-0.42*
SE	0.491	0.561	-0.015	0.008	-0.019
		0.609	*1.868*	*1.361*	*0.308*
SW	0.387	0.562	-0.014	0.018	-0.016
		0.382	*1.039*	*1.983*	*0.181*
WM	0.199	-0.176	-0.004	0.015	0.044
		0.111	*0.375*	*1.592*	*0.482*
Y	0.323	-0.6	0.013	0.022	0.004
		0.301	*1.1*	*1.728*	*0.034*
ALL	0.232	0.407	-0.001	0.018	-0.017
		0.862	*0.565*	*6.207*	*0.568*

Equation 2

	r2	k	dat	f1/f2	wdfe
EA	0.345	0.528	-0.006	0.202	-0.068
		0.504	*0.969*	*2.096*	*1.092*
EM	0.269	-0.48	0.004	0.157	-0.021
		0.465	*0.695*	*1.467*	*0.334*
GL	0.41	0.548	-0.001	0.269	-0.12
		0.429	*0.101*	*2.098*	*1.461*
N	0.823	-0.732	0.031	0.406	0.111
		0.606	*4.347*	*3.386*	*1.52*
NW	0.405	-0.25	-0.004	0.261	-0.068
		0.217	*0.663*	*2.664*	*0.966*
SE	0.494	0.365	-0.014	0.143	-0.039
		0.381	*1.515*	*1.388*	*0.596*
SW	0.445	0.126	-0.017	0.298	-0.036
		0.087	*1.422*	*2.329*	*0.413*
WM	0.263	-0.609	-0.007	0.283	0.019
		0.388	*0.737*	*1.93*	*0.203*
Y	0.741	-1.069	-0.005	-0.181	0.112
		1.252	*0.613*	*1.036*	*4.263*
ALL	0.278	-0.135	-0.003	0.31	-0.045
		0.279	*1.199*	*7.01*	*1.575*

Equation 3

	r2	k	dat	ln(f1/f2)	wdfe
EA	0.562	0.4	-0.007	1.175	-0.069
		0.484	*1.297*	*3.469*	*1.363*
EM	0.311	-0.319	0.001	0.866	-0.017
		0.32	*0.101*	*1.597*	*0.273*
GL	0.681	0.412	0.009	1.814	-0.15
		0.455	*0.942*	*4.181*	*2.436*
N	0.838	-0.317	0.023	2.069	0.099
		0.286	*2.936*	*3.675*	*1.417*
NW	0.57	-0.14	-0.008	1.517	-0.083
		0.149	*1.609*	*3.75*	*1.369*
SE	0.64	0.262	-0.003	1.201	-0.08
		0.36	*0.335*	*2.672*	*1.361*
SW	0.576	0.232	-0.021	1.54	-0.027
		0.192	*1.984*	*3.239*	*0.361*
WM	0.326	0.356	-0.013	1.48	0.019
		0.247	*1.261*	*2.258*	*0.214*
Y	0.346	-0.667	0.001	1.864	-0.048
		0.34	*0.096*	*1.864*	*0.388*
ALL	0.395	-0.094	-0.005	1.619	-0.044
		0.22	*2.257*	*9.162*	*1.683*

Equation 4

	r2	k	dat	dfq	dfe
EA	0.246	1.592	-0.006	0.011	0.002
		1.808	*0.898*	*1.508*	*0.109*
EM	0.447	0.551	0.001	0.008	0.026
		0.646	*0.109*	*1.344*	*1.336*
GL	0.312	2.04	-0.008	0.014	0.004
		1.816	*0.63*	*1.369*	*0.177*
N	0.866	0.148	0.026	0.015	0.065
		0.163	*4.54*	*2.311*	*3.542*
NW	0.479	1.361	0	0.011	0.032
		1.421	*0.049*	*1.676*	*1.665*
SE	0.49	0.879	-0.016	0.007	0.005
		0.991	*2.163*	*1.079*	*0.271*
SW	0.549	2.12	-0.019	0.008	0.045
		2.098	*1.722*	*0.943*	*2.002*
WM	0.525	1.343	-0.009	0.004	0.064
		1.233	*1.194*	*0.459*	*2.815*
Y	0.467	1.448	0.006	0.012	0.06
		0.838	*0.53*	*0.989*	*1.721*
ALL	0.337	1.745	-0.004	0.011	0.038
		4.699	*1.574*	*3.656*	*4.585*

Equation 5

	r2	k	dat	f1/f2	dfe
EA	0.278	1.248	-0.005	0.212	-0.006
		1.281	*0.782*	*1.691*	*0.257*
EM	0.389	0.793	0	0.086	0.03
		0.86	*0.018*	*0.767*	*1.387*
GL	0.297	1.843	-0.008	0.227	-0.001
		1.484	*0.649*	*1.267*	*0.022*
N	0.867	0.061	0.024	0.253	0.061
		0.055	*4.102*	*2.278*	*3.123*
NW	0.448	1.418	-0.002	0.166	0.029
		1.377	*0.279*	*1.311*	*1.363*
SE	0.479	0.823	-0.016	0.114	0.002
		0.872	*2.072*	*0.956*	*0.128*
SW	0.654	1.965	-0.021	0.144	0.041
		1.786	*2.017*	*1.014*	*1.703*
WM	0.531	1.204	-0.01	0.083	0.061
		1.058	*1.289*	*0.589*	*2.519*
Y	0.447	1.628	0.006	0.158	0.061
		0.893	*0.402*	*0.736*	*1.621*
ALL	0.335	1.577	-0.004	0.188	0.034
		3.838	*1.865*	*3.589*	*3.732*

Equation 6

	r2	k	dat	ln(f1/f2)	dfe
EA	0.599	0.283	-0.003	1.704	-0.034
		0.378	*0.572*	*3.739*	*1.738*
EM	0.397	0.791	-0.002	0.0602	0.028
		0.893	*0.273*	*0.862*	*1.281*
GL	0.651	0.769	0.011	2.733	-0.063
		0.877	*1.051*	*3.798*	*2.12*
N	0.863	0.269	0.02	1.287	0.066
		0.298	*3.053*	*2.156*	*2.639*
NW	0.616	1.188	-0.005	1.148	0.014
		1.268	*0.837*	*1.866*	*0.615*
SE	0.61	0.527	-0.008	1.319	-0.018
		0.674	*0.953*	*2.219*	*0.923*
SW	0.612	1.446	-0.022	1.069	0.027
		1.398	*2.335*	*1.674*	*1.071*
WM	0.53	1.246	-0.011	0.413	0.069
		1.119	*1.344*	*0.562*	*2.197*
Y	0.442	1.795	0.002	0.769	0.058
		1.031	*0.178*	*0.674*	*1.441*
ALL	0.399	1.077	-0.006	1.28	0.018
		2.726	*2.442*	*5.311*	*1.939*

Ratio of Access Time

Equation 1

	r2	k	rat	dfq	wdfe
EA	0.359	2.113	-1.004	0.011	-0.064
		1.71	*1.487*	*1.791*	*0.868*
EM	0.378	-1.043	0.243	0.011	-0.034
		0.871	*1.152*	*1.825*	*0.513*
GL	0.369	1.926	-0.984	0.014	-0.093
		0.869	*0.486*	*1.481*	*1.203*
N	0.803	-6.736	6.165	0.025	0.145
		3.358	*4.84*	*3.278*	*1.909*
NW	0.439	0.461	-0.338	0.016	-0.083
		0.424	*1.271*	*2.367*	*1.05*
SE	0.592	4.279	-4.019	0.004	-0.031
		2.799	*2.654*	*0.723*	*0.578*
SW	0.335	0.733	-0.593	0.02	-0.038
		0.312	*0.383*	*2.186*	*0.418*
WM	0.226	0.472	-0.304	0.016	0.053
		0.257	*0.751*	*1.646*	*0.556*
Y	0.281	-1.151	0.657	0.023	-0.002
		0.462	*0.696*	*1.762*	*0.017*
ALL	0.244	0.719	-0.216	0.018	-0.017
		1.369	*1.508*	*6.289*	*0.58*

Equation 2

	r2	k	rat	f1/f2	wdfe
EA	0.404	1.668	-0.942	0.188	-0.072
		1.353	*1.449*	*2.066*	*1.212*
EM	0.289	-0.907	0.181	0.145	-0.04
		0.709	*0.693*	*1.238*	*0.57*
GL	0.426	1.56	-1.056	0.235	-0.115
		0.717	*0.568*	*1.742*	*1.504*
N	0.791	-6.25	5.297	0.406	0.1
		3.029	*3.778*	*3.097*	*1.271*
NW	0.502	0.034	-0.405	0.265	-0.118
		0.031	*1.633*	*2.769*	*1.604*
SE	0.603	3.899	-3.781	0.087	-0.041
		2.343	*2.433*	*0.909*	*0.753*
SW	0.361	0.491	-0.831	0.315	-0.065
		0.211	*0.55*	*2.325*	*0.724*
WM	0.286	0.128	-0.382	0.276	0.03
		0.071	*0.972*	*1.964*	*0.325*
Y	0.294	-1.198	0.269	0.384	-0.046
		0.485	*0.27*	*1.838*	*0.363*
ALL	0.296	0.267	-0.308	0.316	-0.046
		0.518	*2.214*	*7.228*	*1.634*

Equation 3

	r2	k	rat	ln(f1/f2)	wdfe
EA	0.61	1.557	-0.945	1.113	-0.073
		1.58	*1.797*	*3.512*	*1.625*
EM	0.323	-0.666	0.121	0.757	-0.032
		0.63	*0.455*	*1.475*	*0.456*
GL	0.677	-0.978	1.404	1.696	-0.137
		0.536	*0.862*	*3.736*	*2.377*
N	0.822	4.363	3.864	2.159	0.09
		2.196	*2.617*	*3.63*	*1.237*
NW	0.671	0.106	-0.509	1.394	-0.135
		0.127	*2.517*	*4.15*	*2.238*
SE	0.661	2.004	-1.812	0.911	-0.067
		0.97	*0.895*	*1.689*	*1.248*
SW	0.47	1.151	-1.347	1.586	-0.058
		0.563	*0.974*	*2.965*	*0.705*
WM	0.35	0.67	-0.565	1.397	0.035
		0.405	*1.436*	*2.299*	*0.407*
Y	0.36	-0.31	-0.286	2.056	-0.059
		0.133	*0.27*	*2.147*	*0.476*
ALL	0.417	0.429	-0.409	1.643	-0.046
		0.945	*3.195*	*9.491*	*1.178*

Equation 4

	r2	k	rat	dfq	dfe
EA	0.315	2.899	-1.026	0.011	0.003
		2.237	*1.41*	*1.485*	*0.157*
EM	0.451	0.934	-0.087	0.008	0.034
		0.733	*0.317*	*1.256*	*1.329*
GL	0.309	3.402	-1.293	0.013	0.002
		1.541	*0.601*	*1.18*	*0.086*
N	0.867	-4.379	4.47	0.015	0.066
		2.289	*3.961*	*2.102*	*3.285*
NW	0.486	1.542	-0.087	0.012	0.029
		1.674	*0.391*	*1.61*	*1.485*
SE	0.583	4.784	-4.376	0.005	-0.005
		3.935	*2.864*	*0.723*	*0.299*
SW	0.447	2.585	-0.866	0.013	0.038
		1.399	*0.626*	*1.363*	*1.561*
WM	0.541	1.864	-0.429	0.004	0.062
		1.491	*1.366*	*0.484*	*2.835*
Y	0.454	1.678	0.132	0.012	0.065
		0.707	*0.154*	*0.981*	*1.872*
ALL	0.352	2.18	-0.314	0.012	0.038
		5.032	*2.341*	*3.739*	*4.71*

Equation 5

	r2	k	rat	f1/f2	dfe
EA	0.326	2.449	-0.883	0.192	-0.004
		1.694	*1.199*	*1.558*	*0.178*
EM	0.416	1.395	-0.201	0.099	0.041
		1.172	*0.715*	*0.903*	*1.67*
GL	0.309	3.433	-1.591	0.211	-0.003
		1.567	*0.788*	*1.176*	*0.122*
N	0.866	-4.035	4.071	0.249	0.062
		2.139	*3.518*	*2.049*	*2.924*
NW	0.454	1.537	-0.106	0.168	0.026
		1.433	*0.458*	*1.341*	*1.17*
SE	0.59	4.609	-4.345	0.09	-0.008
		3.642	*2.908*	*0.851*	*0.467*
SW	0.421	2.781	-1.064	0.181	0.036
		1.468	*0.772*	*1.127*	*1.31*
WM	0.544	1.806	-0.447	0.075	0.06
		1.389	*1.422*	*0.543*	*2.518*
Y	0.436	1.917	0.018	0.172	0.064
		0.806	*0.02*	*0.79*	*1.729*
ALL	0.352	2.037	-0.357	0.195	0.033
		4.453	*2.66*	*3.754*	*3.771*

Equation 6

	r2	k	rat	ln(f1/f2)	dfe
EA	0.624	1.069	-0.574	1.627	-0.031
		0.965	*1.027*	*3.611*	*1.678*
EM	0.416	1.323	-0.184	0.473	0.037
		1.08	*0.663*	*0.905*	*1.409*
GL	0.676	-1.95	2.576	3.053	-0.055
		0.927	*1.418*	*3.922*	*2.361*
N	0.869	-3.172	3.342	1.358	0.055
		1.749	*2.685*	*2.161*	*2.459*
NW	0.526	1.345	-0.228	1.159	0.009
		1.405	*0.991*	*1.936*	*0.344*
SE	0.649	2.986	-2.712	1.017	-0.019
		1.782	*1.491*	*1.637*	*1.064*
SW	0.473	2.702	-1.44	1.177	0.022
		1.575	*1.062*	*1.577*	*0.748*
WM	0.542	1.908	-0.484	0.346	0.058
		1.552	*1.466*	*0.493*	*2.198*
Y	0.443	2.159	-0.178	0.946	0.058
		0.958	*0.186*	*0.842*	*1.446*
ALL	0.418	1.6	-0.415	1.314	0.018
		3.716	*3.246*	*5.531*	*1.884*

Difference in Access Time

LEISURE OTHER PAX UK SHORT HAUL MODEL

Equation 1

	r2	k	dat	dfq	wdfe
EA	0.457	0.818	-0.012	0.006	-0.106
		0.899	*2.101*	*1.122*	*1.85*
EM	0.546	-0.249	0.004	0.009	-0.046
		0.469	*1.273*	*2.565*	*1.4*
GL	0.673	0.620	-0.06	-0.007	-0.146
		0.378	*3.685*	*0.614*	*1.332*
N	0.366	-0.136	0.006	0.019	0.023
		0.096	*0.692*	*2.221*	*0.265*
NW	0.34	0.32	-0.005	0.024	0.067
		0.178	*0.494*	*2.163*	*0.751*
SE	0.607	0.454	-0.016	0.006	-0.063
		0.588	*2.296*	*1.169*	*1.196*
SW	0.494	0.27	-0.001	0.019	-0.069
		0.248	*0.136*	*2.856*	*1.025*
WM	0.271	-0.177	-0.008	0.014	-0.024
		0.14	*0.982*	*1.799*	*0.315*
Y	0.46	-0.243	0.01	0.02	0.065
		0.182	*1.343*	*2.339*	*1.025*
ALL	0.282	0.647	-0.012	0.015	-0.046
		1.329	*4.891*	*4.928*	*1.512*

Equation 2

	r2	k	dat	f1/f2	wdfe
EA	0.505	0.497	-0.012	0.133	-0.117
		0.538	*2.243*	*1.566*	*2.144*
EM	0.49	-0.361	0.003	0.128	-0.057
		0.617	*0.817*	*2.154*	*1.655*
GL	0.672	0.763	-0.06	-0.103	-0.135
		0.441	*3.646*	*0.589*	*1.203*
N	0.34	-0.44	0.002	0.301	-0.011
		0.301	*0.244*	*2.079*	*0.13*
NW	0.412	-0.31	-0.009	0.416	0.033
		0.175	*1.003*	*2.565*	*0.297*
SE	0.588	0.387	-0.016	0.079	-0.072
		0.48	*2.046*	*0.895*	*1.275*
SW	0.544	-0.101	-0.005	0.301	-0.069
		0.094	*0.603*	*3.201*	*1.375*
WM	0.326	-0.532	-0.011	0.247	-0.047
		0.421	*1.374*	*2.099*	*0.633*
Y	0.457	-0.602	0.007	0.319	0.048
		0.433	*0.8*	*2.318*	*0.575*
ALL	0.328	0.094	-0.014	0.269	-0.071
		0.189	*5.559*	*5.906*	*2.412*

Equation 3

	r2	k	dat	ln(f1/f2)	wdfe
EA	0.628	0.365	-0.013	0.831	-0.119
		0.46	*2.699*	*2.627*	*2.5*
EM	0.559	-0.251	-0.001	0.757	-0.054
		0.48	*0.143*	*2.666*	*1.677*
GL	0.662	0.276	-0.054	0.104	-0.158
		0.163	*3.072*	*0.128*	*1.349*
N	0.397	-0.186	-0.005	1.649	-0.022
		0.138	*0.48*	*2.399*	*0.26*
NW	0.506	-0.04	-0.015	2.11	0.014
		0.026	*1.675*	*3.153*	*0.139*
SE	0.68	0.272	-0.008	0.827	-0.104
		0.367	*0.939*	*2.049*	*1.97*
SW	0.773	-0.024	-0.009	1.598	-0.08
		0.033	*1.449*	*5.623*	*1.771*
WM	0.449	-0.376	-0.016	1.385	-0.048
		0.343	*2.125*	*2.797*	*0.714*
Y	0.487	-0.292	0	1.66	0.038
		0.224	*0.027*	*2.512*	*0.461*
ALL	0.437	0.08	-0.016	1.485	-0.07
		0.183	*6.897*	*8.173*	*2.608*

Equation 4

	r2	k	dat	dfq	dfe
EA	0.31	1.793	-0.011	0.009	-0.012
		2.1	*1.606*	*1.259*	*0.589*
EM	0.488	0.613	0.002	0.008	0.009
		1.142	*0.459*	*2.068*	*0.701*
GL	0.624	1.854	-0.066	-0.008	-0.011
		1.228	*3.909*	*0.408*	*0.323*
N	0.46	0.862	0.001	0.014	0.036
		0.684	*0.123*	*1.537*	*1.417*
NW	0.544	1.334	-0.007	0.011	0.065
		0.963	*0.95*	*1.063*	*2.39*
SE	0.591	0.604	-0.02	0.008	-0.014
		0.769	*3.086*	*1.326*	*0.96*
SW	0.55	2.037	-0.007	0.013	0.029
		2.47	*0.821*	*1.767*	*1.595*
WM	0.492	1.538	-0.012	0.008	0.044
		1.623	*1.71*	*0.869*	*2.218*
Y	0.621	0.685	0.003	0.011	0.055
		0.625	*0.432*	*1.379*	*2.477*
ALL	0.321	1.998	-0.014	0.01	0.028
		4.981	*5.617*	*3.104*	*3.066*

Equation 5

	r2	k	dat	f1/f2	dfe
EA	0.347	1.442	-0.01	0.184	-0.02
		1.535	*1.519*	*1.518*	*0.908*
EM	0.393	0.753	0.001	0.1	0.01
		1.241	*0.205*	*1.375*	*0.745*
GL	0.629	2.125	-0.067	-0.137	-0.004
		1.296	*4.004*	*0.579*	*0.112*
N	0.425	0.958	-0.001	0.194	0.035
		0.722	*0.072*	*1.242*	*1.278*
NW	0.558	1.066	-0.009	0.219	0.057
		0.763	*1.167*	*1.253*	*1.939*
SE	0.556	0.657	-0.021	0.091	-0.014
		0.791	*2.973*	*0.868*	*0.832*
SW	0.535	1.944	-0.011	0.194	0.026
		2.131	*1.239*	*1.638*	*1.289*
WM	0.487	1.521	-0.013	0.1	0.042
		1.519	*1.832*	*0.803*	*1.993*
Y	0.614	0.658	0.002	0.174	0.052
		0.576	*0.223*	*1.295*	*2.219*
ALL	0.325	1.781	-0.015	0.182	0.023
		4.035	*5.899*	*3.236*	*2.315*

Equation 6

	r2	k	dat	ln(f1/f2)	dfe
EA	0.621	0.505	-0.008	1.55	-0.046
		0.682	*1.526*	*3.45*	*2.431*
EM	0.459	0.673	-0.002	0.67	0.007
		1.226	*0.387*	*1.859*	*0.601*
GL	0.624	1.122	-0.057	0.583	-0.034
		0.677	*2.836*	*0.429*	*0.726*
N	0.442	1.002	-0.004	1.132	0.028
		0.805	*0.489*	*1.387*	*0.979*
NW	0.574	1.031	-0.012	1.268	0.045
		0.761	*1.501*	*1.424*	*1.328*
SE	0.686	0.335	-0.012	1.207	-0.033
		0.5	*1.79*	*2.37*	*2.032*
SW	0.71	1.195	-0.013	1.473	0.005
		1.637	*1.88*	*3.305*	*0.3*
WM	0.519	1.308	-0.015	0.748	0.034
		1.381	*2.125*	*1.196*	*1.484*
Y	0.608	0.818	-0.001	0.875	0.049
		0.748	*0.141*	*1.22*	*1.921*
ALL	0.412	1.063	-0.016	1.419	0.003
		2.552	*6.801*	*5.583*	*0.278*

Ratio of Access Time

Equation 1

	r2	k	ret	dfq	wdfa
EA	0.554	2.726	-1.59	0.005	-0.116
		2.61	*2.787*	*1.028*	*2.231*
EM	0.59	-0.789	0.193	0.008	-0.068
		1.24	*1.72*	*2.535*	*1.957*
GL	0.57	9.136	-8.569	-0.014	-0.248
		2.7	*2.773*	*0.972*	*2.091*
N	0.349	-0.696	0.609	0.02	0.019
		0.305	*0.421*	*2.237*	*0.218*
NW	0.512	0.969	-0.766	0.021	-0.023
		0.619	*2.052*	*2.204*	*0.205*
SE	0.625	3.653	-3.402	0.004	-0.062
		2.61	*2.453*	*0.645*	*1.688*
SW	0.505	0.86	-0.546	0.019	-0.065
		0.631	*0.503*	*2.971*	*1.004*
WM	0.384	0.925	-0.54	0.014	-0.009
		0.669	*1.777*	*1.967*	*0.131*
Y	0.404	-0.63	0.497	0.021	0.079
		0.371	*0.771*	*2.341*	*0.905*
ALL	0.429	1.665	-0.84	-0.033	0.101
		4.782	*6.245*	*4.001*	*6.232*

Equation 2

	r2	k	ret	f1/f2	wdfa
EA	0.582	2.446	-1.559	0.105	-0.125
		2.311	*2.825*	*1.364*	*2.483*
EM	0.499	-0.686	0.135	0.116	-0.072
		0.978	*0.942*	*1.811*	*1.863*
GL	0.547	8.346	-7.706	-0.126	-0.237
		2.374	*2.564*	*0.678*	*1.918*
N	0.337	-0.317	-0.078	0.318	-0.016
		0.136	*0.05*	*2.174*	*0.184*
NW	0.593	0.261	-0.873	0.376	-0.072
		0.186	*2.525*	*2.832*	*0.696*
SE	0.622	3.587	-3.399	0.051	-0.087
		2.314	*2.349*	*0.673*	*1.723*
SW	0.552	0.625	-0.775	0.306	-0.091
		0.392	*0.75*	*3.303*	*1.474*
WM	0.429	0.655	-0.606	0.24	-0.03
		0.483	*2.048*	*2.261*	*0.435*
Y	0.428	-0.677	0.141	0.35	0.038
		0.406	*0.209*	*2.483*	*0.445*
ALL	0.317	1.024	-0.778	0.272	-0.075
		1.891	*5.325*	*5.916*	*2.539*

Equation 3

	r2	k	ret	ln(f1/f2)	wdfa
EA	0.665	2.284	-1.56	0.712	-0.127
		2.548	*3.259*	*2.469*	*2.904*
EM	0.571	-0.495	0.078	0.636	-0.064
		0.739	*0.56*	*2.36*	*1.773*
GL	0.533	7.165	-6.927	-0.059	-0.248
		1.797	*1.945*	*0.053*	*1.967*
N	0.417	1.226	-1.318	1.77	-0.026
		0.542	*0.787*	*2.624*	*0.308*
NW	0.698	0.47	-1.017	1.897	-0.093
		0.381	*3.398*	*3.817*	*1.05*
SE	0.676	1.779	-1.584	0.749	-0.112
		0.923	*0.836*	*1.488*	*2.233*
SW	0.794	1.194	-1.306	1.647	-0.065
		1.147	*1.864*	*6.05*	*2.021*
WM	0.558	1.062	-0.769	1.322	-0.025
		0.944	*2.89*	*3.135*	*0.422*
Y	0.498	0.131	-0.347	1.845	0.028
		0.085	*0.496*	*2.924*	*0.344*
ALL	0.387	1.982	-0.85	1.148	0.009
		5.206	*5.95*	*2.411*	*0.664*

Equation 4

	r2	k	ret	dfq	dfa
EA	0.381	3.578	-1.426	0.008	-0.014
		2.867	*2.035*	*1.214*	*0.715*
EM	0.479	0.822	-0.02	0.008	0.013
		1.012	*0.116*	*1.962*	*0.825*
GL	0.433	11.62	-8.997	-0.008	-0.033
		3.193	*2.536*	*0.416*	*0.809*
N	0.462	1.364	-0.277	0.014	0.039
		0.565	*0.195*	*1.543*	*1.536*
NW	0.636	2.031	-0.575	0.013	0.05
		1.597	*1.985*	*1.366*	*1.952*
SE	0.618	4.898	-4.627	0.006	-0.024
		4.408	*3.13*	*0.961*	*1.613*
SW	0.553	2.804	-0.876	0.014	0.027
		2.067	*0.864*	*2.046*	*1.514*
WM	0.609	2.517	-0.65	0.006	0.043
		2.565	*2.665*	*1.004*	*2.521*
Y	0.615	1.104	-0.069	0.011	0.059
		0.738	*0.127*	*1.378*	*2.698*
ALL	0.298	2.846	-0.761	0.011	0.024
		5.92	*5.111*	*3.311*	*2.666*

Equation 5

	r2	k	ret	f1/f2	dfa
EA	0.397	3.163	-1.304	0.159	-0.02
		2.284	*1.847*	*1.344*	*0.951*
EM	0.422	1.229	-0.14	0.112	0.02
		1.587	*0.768*	*1.568*	*1.241*
GL	0.426	11.05	-8.508	-0.066	-0.036
		3.043	*2.543*	*0.22*	*0.775*
N	0.433	1.771	-0.6	0.204	0.037
		0.73	*0.404*	*1.31*	*1.38*
NW	0.647	1.761	-0.608	0.233	0.041
		1.322	*2.111*	*1.495*	*1.488*
SE	0.61	4.933	-4.739	0.062	-0.025
		4.186	*3.406*	*0.828*	*1.596*
SW	0.521	2.94	-1.116	0.212	0.023
		2.09	*1.07*	*1.781*	*1.148*
WM	0.6	2.546	-0.674	0.094	0.042
		2.486	*2.723*	*0.86*	*2.233*
Y	0.617	1.154	-0.199	0.169	0.055
		0.783	*0.361*	*1.401*	*2.39*
ALL	0.302	2.667	-0.803	0.197	0.019
		5.271	*5.415*	*3.445*	*1.895*

Equation 6

	r2	k	ret	ln(f1/f2)	dfa
EA	0.649	1.635	-1.008	1.462	-0.046
		1.66	*1.642*	*3.314*	*2.53*
EM	0.478	1.032	-0.128	0.637	0.013
		1.362	*0.745*	*1.975*	*0.793*
GL	0.446	7.407	-5.984	1.236	-0.069
		1.482	*1.386*	*0.669*	*1.241*
N	0.464	2.462	-1.311	1.244	0.029
		1.078	*0.83*	*1.56*	*1.025*
NW	0.681	1.643	-0.755	1.452	0.022
		1.356	*2.592*	*1.915*	*0.689*
SE	0.688	3.131	-2.97	1.061	-0.037
		2.076	*1.814*	*1.896*	*2.368*
SW	0.717	2.613	-1.601	1.61	0.001
		2.546	*1.973*	*3.608*	*0.039*
WM	0.637	2.391	-0.764	0.732	0.032
		2.6	*3.093*	*1.395*	*1.619*
Y	0.624	1.425	-0.411	1.03	0.049
		1.027	*0.699*	*1.489*	*1.963*
ALL	0.385	2.063	-0.869	1.449	-0.001
		4.412	*6.203*	*5.562*	*0.059*

Appendix B Difference in Access Time

BUSINESS PAX FOREIGN SHORT HAUL MODEL

Equation 1

	r2	k	det	dfq	wdfe
EA	0.577	0.843	-0.017	0.019	0.009
		0.854	*2.719*	*3.107*	*0.147*
EM	0.494	-0.368	-0.002	0.019	0.033
		0.397	*0.273*	*3.178*	*0.571*
GL	0.467	1.317	-0.023	0.018	-0.061
		0.796	*1.408*	*1.589*	*0.734*
N	0.696	-0.001	0.022	0.028	0.231
		0.001	*2.618*	*3.15*	*2.594*
NW	0.507	0.09	0.006	0.041	0.275
		0.039	*0.465*	*2.915*	*1.878*
SE	0.875	0.336	-0.026	0.015	0.017
		0.609	*5.255*	*3.875*	*0.439*
SW	0.545	0.399	-0.011	0.024	-0.013
		0.309	*0.96*	*3.051*	*0.165*
WM	0.32	-0.248	-0.009	0.024	0.059
		0.135	*0.831*	*2.146*	*0.629*
Y	0.458	-0.416	0.005	0.029	0.119
		0.245	*0.503*	*2.709*	*1.126*
ALL	0.38	0.629	-0.012	0.026	0.051
		1.164	*4.424*	*7.823*	*1.498*

Equation 2

	r2	k	det	f1/f2	wdfe
EA	0.626	0.292	-0.017	0.318	-0.021
		0.296	*2.89*	*3.511*	*0.358*
EM	0.414	-0.632	-0.004	0.284	0.008
		0.61	*0.634*	*2.69*	*0.129*
GL	0.474	0.867	-0.022	0.287	-0.111
		0.5	*1.34*	*1.645*	*0.985*
N	0.69	-0.506	0.017	0.459	0.179
		0.335	*1.828*	*3.062*	*1.964*
NW	0.559	-0.824	-0.002	0.676	0.186
		0.367	*0.141*	*3.288*	*1.333*
SE	0.83	0.137	-0.025	0.208	-0.01
		0.203	*3.948*	*2.865*	*0.204*
SW	0.601	-0.065	-0.016	0.364	-0.036
		0.067	*1.547*	*3.49*	*0.507*
WM	0.389	-0.851	-0.015	0.424	0.02
		0.471	*1.309*	*2.522*	*0.189*
Y	0.44	-0.92	0	0.463	0.065
		0.515	*0.046*	*2.623*	*0.606*
ALL	0.434	-0.136	-0.014	0.445	0.01
		0.253	*5.368*	*8.906*	*0.303*

Equation 3

	r2	k	det	ln(f1/f2)	wdfe
EA	0.676	0.212	-0.018	1.731	-0.021
		0.366	*5.252*	*7.725*	*0.626*
EM	0.574	-0.415	-0.012	1.731	0.015
		0.489	*1.909*	*3.755*	*0.294*
GL	0.657	0.644	-0.01	2.048	-0.147
		0.477	*0.697*	*3.168*	*1.603*
N	0.709	-0.031	0.008	2.358	0.167
		0.022	*0.748*	*3.267*	*1.872*
NW	0.624	-0.251	-0.01	3.265	0.16
		0.126	*0.882*	*3.817*	*1.233*
SE	0.947	0.142	-0.013	1.469	-0.053
		0.369	*3.134*	*7.095*	*1.922*
SW	0.8	0.073	-0.021	1.977	-0.027
		0.086	*2.834*	*5.923*	*0.504*
WM	0.509	-0.521	-0.023	2.301	0.019
		0.336	*2.166*	*3.261*	*0.204*
Y	0.462	-0.47	-0.01	2.41	0.05
		0.283	*0.828*	*2.865*	*0.479*
ALL	0.569	-0.05	-0.017	2.292	0.012
		0.109	*7.348*	*12.047*	*0.412*

Equation 4

	r2	k	det	dfq	dfe
EA	0.662	1.518	-0.02	0.014	0.03
		2.07	*3.444*	*2.289*	*1.676*
EM	0.718	0.731	-0.01	0.013	0.047
		1.11	*1.934*	*2.639*	*3.053*
GL	0.441	2.197	-0.027	0.017	0.002
		1.51	*1.693*	*1.233*	*0.067*
N	0.708	0.042	0.01	0.016	0.076
		0.03	*1.133*	*1.616*	*2.704*
NW	0.699	0.668	-0.002	0.018	0.116
		0.406	*0.195*	*1.411*	*3.579*
SE	0.88	0.443	-0.025	0.013	0.008
		0.847	*5.643*	*3.295*	*0.841*
SW	0.721	1.994	-0.016	0.014	0.048
		2.452	*1.864*	*1.999*	*2.636*
WM	0.635	1.594	-0.016	0.01	0.08
		1.322	*1.91*	*1.042*	*3.165*
Y	0.643	0.83	-0.005	0.017	0.075
		0.615	*0.618*	*1.742*	*2.759*
ALL	0.521	1.726	-0.016	0.016	0.058
		4.289	*6.225*	*4.573*	*6.445*

Equation 5

	r2	k	det	f1/f2	dfe
EA	0.66	1.241	-0.019	0.243	0.022
		1.491	*3.261*	*2.268*	*1.127*
EM	0.652	0.867	-0.011	0.172	0.048
		1.141	*2.012*	*1.89*	*2.747*
GL	0.428	1.995	-0.028	0.258	-0.003
		1.239	*1.706*	*1.111*	*0.082*
N	0.723	-0.314	0.008	0.301	0.066
		0.226	*0.86*	*1.836*	*2.376*
NW	0.717	0.256	-0.004	0.344	0.103
		0.154	*0.482*	*1.682*	*2.987*
SE	0.834	0.466	-0.026	0.179	0.007
		0.688	*4.75*	*2.181*	*0.527*
SW	0.716	1.84	-0.02	0.224	0.043
		2.061	*2.378*	*1.939*	*2.191*
WM	0.642	1.411	-0.018	0.18	0.075
		1.125	*2.11*	*1.153*	*2.802*
Y	0.628	0.822	-0.007	0.264	0.071
		0.579	*0.839*	*1.578*	*2.449*
ALL	0.53	1.366	-0.016	0.274	0.05
		3.143	*6.664*	*4.86*	*5.186*

Equation 6

	r2	k	det	ln(f1/f2)	dfe
EA	0.874	0.32	-0.017	1.813	-0.006
		0.61	*4.595*	*5.699*	*0.409*
EM	0.737	0.689	-0.016	1.195	0.04
		1.089	*3.036*	*2.876*	*2.63*
GL	0.694	0.603	-0.004	3.339	-0.069
		0.51	*0.261*	*3.445*	*2.049*
N	0.718	-0.067	0.003	1.551	0.062
		0.05	*0.269*	*1.771*	*2.005*
NW	0.708	0.497	-0.008	1.671	0.093
		0.302	*0.84*	*1.649*	*2.266*
SE	0.943	0.229	-0.016	1.634	-0.015
		0.63	*4.245*	*5.927*	*1.661*
SW	0.824	1.17	-0.022	1.556	0.023
		1.645	*3.403*	*3.586*	*1.359*
WM	0.663	1.249	-0.022	1.132	0.064
		1.05	*2.44*	*1.443*	*2.25*
Y	0.622	1.049	-0.012	1.344	0.066
		0.77	*1.183*	*1.605*	*2.091*
ALL	0.597	0.776	-0.018	1.769	0.031
		1.881	*7.821*	*7.03*	*3.069*

Ratio of Access Time

Equation 1

	r2	k	rat	dfq	wdfe
EA	0.537	3.119	-1.8	0.01	-0.109
		2.505	*2.646*	*1.661*	*1.767*
EM	0.569	-1.224	0.297	0.014	-0.019
		1.193	*1.646*	*2.725*	*0.344*
GL	0.376	5.476	-4.162	0.005	-0.161
		1.65	*1.373*	*0.34*	*1.365*
N	0.526	-2.454	2.451	0.018	0.107
		1.191	*1.874*	*2.281*	*1.371*
NW	0.619	1.222	-1.008	0.02	-0.061
		0.886	*2.984*	*2.331*	*0.615*
SE	0.532	3.176	-2.775	0.007	-0.078
		1.919	*1.693*	*1.047*	*1.362*
SW	0.424	5.429	-5.454	0.026	-0.106
		1.249	*1.909*	*1.565*	*0.633*
WM	0.432	1.328	-0.826	0.019	-0.007
		0.743	*2.1*	*2.079*	*0.08*
Y	0.353	-0.295	0.258	0.028	0.069
		0.122	*0.282*	*2.272*	*0.723*
ALL	0.276	1.454	-0.758	0.02	-0.032
		2.298	*4.327*	*5.633*	*0.892*

Equation 2

	r2	k	rat	f1/f2	wdfe
EA	0.555	2.755	-1.743	0.169	-0.125
		2.155	*2.614*	*1.816*	*2.059*
EM	0.456	-1.047	0.199	0.2	-0.026
		0.91	*0.848*	*1.9*	*0.407*
GL	0.367	5.009	-3.955	0.113	-0.172
		1.504	*1.389*	*0.547*	*1.466*
N	0.532	-2.097	1.775	0.303	0.074
		1.023	*1.275*	*2.325*	*0.943*
NW	0.677	0.63	-1.09	0.343	-0.106
		0.472	*3.54*	*2.867*	*1.163*
SE	0.521	3.076	-2.792	0.096	-0.088
		1.666	*1.619*	*0.901*	*1.456*
SW	0.422	5.218	5.774	0.397	0.142
		1.187	*2.026*	*1.551*	*0.832*
WM	0.45	1.028	-0.907	0.306	-0.034
		0.574	*2.321*	*2.196*	*0.38*
Y	0.379	-0.361	0.236	0.483	0.034
		0.153	*0.246*	*2.416*	*0.275*
ALL	0.307	1.000	-0.855	0.337	-0.063
		1.562	*4.95*	*6.21*	*1.807*

Equation 3

	r2	k	rat	ln(f1/f2)	wdfe
EA	0.669	2.607	-1.746	1.033	-0.127
		2.497	*3.131*	*3.076*	*2.494*
EM	0.534	-0.706	0.106	1.078	-0.013
		0.656	*0.467*	*2.458*	*0.219*
GL	0.469	2.537	-1.736	1.365	-0.194
		0.733	*0.562*	*1.434*	*1.767*
N	0.582	-0.672	0.659	1.642	0.066
		0.331	*0.439*	*2.715*	*0.865*
NW	0.772	0.778	-1.222	1.747	-0.127
		0.727	*-4.714*	*4.058*	*1.642*
SE	0.622	0.528	-0.165	1.145	-0.123
		0.239	*0.066*	*1.966*	*2.142*
SW	0.479	6.000	-6.444	2.069	-0.133
		1.492	*2.369*	*1.967*	*0.823*
WM	0.55	1.594	-1.133	1.654	-0.029
		1.022	*3.052*	*2.886*	*0.348*
Y	0.456	0.755	-0.919	2.565	0.019
		0.346	*0.929*	*2.871*	*0.163*
ALL	0.39	1.163	-0.96	1.739	-0.063
		2.036	*5.871*	*7.852*	*1.909*

Equation 4

	r2	k	rat	dfq	dfe
EA	0.429	3.66	-1.629	0.014	-0.014
		2.752	*2.068*	*1.723*	*0.674*
EM	0.712	1.022	-0.103	0.01	0.045
		1.075	*0.505*	*2.018*	*2.369*
GL	0.3	6.903	-4.369	0.01	-0.026
		2.097	*1.368*	*0.591*	*0.718*
N	0.604	-0.735	1.209	0.01	0.048
		0.335	*0.936*	*1.288*	*2.101*
NW	0.647	2.147	-0.799	0.016	0.028
		1.717	*2.802*	*1.686*	*1.129*
SE	0.531	4.357	-3.963	0.009	-0.023
		3.343	*2.419*	*1.297*	*1.354*
SW	0.456	8.807	-6.018	0.017	0.051
		2.428	*2.219*	*0.925*	*1.064*
WM	0.615	3.205	-0.957	0.01	0.052
		2.441	*2.932*	*1.139*	*2.284*
Y	0.55	2.064	-0.457	0.015	0.076
		0.939	*0.573*	*1.367*	*2.363*
ALL	0.326	2.927	-0.843	0.014	0.033
		5.293	*4.921*	*3.644*	*3.179*

Equation 5

	r2	k	rat	f1/f2	dfe
EA	0.427	3.383	-1.464	0.23	-0.022
		2.14	*1.818*	*1.705*	*0.917*
EM	0.678	1.511	-0.246	0.132	0.063
		1.661	*1.146*	*1.582*	*2.802*
GL	0.309	6.641	-4.449	0.187	-0.033
		2.046	*1.488*	*0.704*	*0.824*
N	0.614	-0.552	0.898	0.192	0.044
		0.261	*0.691*	*1.408*	*1.847*
NW	0.653	1.892	-0.835	0.27	0.019
		1.435	*2.93*	*1.75*	*0.708*
SE	0.513	4.426	-4.148	0.128	-0.026
		3.172	*2.518*	*1.094*	*1.378*
SW	0.436	9.37	-6.312	0.192	0.053
		2.526	*2.297*	*0.612*	*0.988*
WM	0.597	3.334	-0.99	0.128	0.052
		2.405	*2.957*	*0.863*	*2.044*
Y	0.551	2.15	-0.645	0.272	0.071
		0.99	*0.794*	*1.373*	*2.078*
ALL	0.321	2.804	-0.895	0.233	0.028
		4.785	*5.208*	*3.505*	*2.45*

Equation 6

	r2	k	rat	ln(f1/f2)	dfe
EA	0.717	1.806	-1.104	1.919	-0.054
		1.555	*1.92*	*4.139*	*2.813*
EM	0.868	1.371	-0.226	0.671	0.047
		1.487	*1.082*	*1.709*	*2.342*
GL	0.553	-0.117	0.672	3.524	-0.098
		0.032	*0.213*	*2.603*	*2.405*
N	0.628	0.114	0.287	1.103	0.037
		0.066	*0.206*	*1.569*	*1.493*
NW	0.718	1.652	-1.02	1.769	-0.007
		1.452	*3.731*	*2.513*	*0.224*
SE	0.645	1.952	-1.683	1.515	-0.042
		1.147	*0.91*	*2.398*	*2.372*
SW	0.462	9.066	-6.747	1.443	0.033
		2.643	*2.482*	*0.965*	*0.559*
WM	0.623	3.212	-1.1	0.901	0.041
		2.54	*3.237*	*1.249*	*1.507*
Y	0.564	2.517	-0.967	1.531	0.061
		1.238	*1.122*	*1.511*	*1.66*
ALL	0.377	2.321	-0.962	1.539	0.01
		4.16	*5.813*	*5.000*	*0.806*

Difference in Access Time

LEISURE IT PAX FOREIGN SHORT HAUL MODEL

Equation 1

	r2	k	dat	dfq	wdfs
EA	0.311	1.943	-0.022	0.026	0.01
		0.86	*1.521*	*1.822*	*0.072*
EM	0.52	-0.994	0.005	0.042	0.119
		0.47	*0.418*	*3.061*	*0.908*
GL	0.367	2.015	-0.04	0.012	-0.101
		0.793	*1.677*	*0.715*	*0.595*
N	0.259	0.284	-0.01	0.006	0.127
		0.192	*1.156*	*0.655*	*1.394*
NW	0.234	0.96	-0.007	0.031	0.058
		0.33	*0.428*	*1.725*	*0.312*
SE	0.757	1.183	-0.073	0.01	0.178
		0.712	*4.867*	*0.92*	*1.568*
SW	0.491	0.419	0.012	0.036	-0.158
		0.202	*0.66*	*3*	*1.233*
WM	0.181	-0.385	0.002	0.022	-0.116
		0.144	*0.128*	*1.316*	*0.711*
Y	0.55	0.18	0.007	0.051	0.057
		0.077	*0.524*	*3.447*	*0.393*
ALL	0.289	1.285	-0.018	0.03	-0.005
		1.588	*4.285*	*5.942*	*0.099*

Equation 2

	r2	k	dat	f1/f2	wdfs
EA	0.412	0.884	-0.022	0.489	-0.033
		0.398	*1.686*	*2.4*	*0.253*
EM	0.421	-1.473	0	0.596	0.065
		0.611	*0.032*	*2.423*	*0.453*
GL	0.383	1.541	-0.037	0.239	-0.128
		0.582	*1.487*	*0.896*	*0.743*
N	0.275	0.071	-0.012	0.125	0.114
		0.047	*1.296*	*0.829*	*1.246*
NW	0.286	0.15	-0.012	0.535	-0.011
		0.061	*0.817*	*2*	*0.063*
SE	0.761	0.893	-0.07	0.19	0.151
		0.518	*4.376*	*1.024*	*1.273*
SW	0.52	-0.23	0.004	0.585	-0.196
		0.11	*0.222*	*3.191*	*1.561*
WM	0.234	-1.036	-0.003	0.406	-0.152
		0.386	*0.176*	*1.621*	*0.965*
Y	0.471	-0.491	-0.001	0.76	-0.031
		0.186	*0.072*	*2.907*	*0.195*
ALL	0.339	0.331	-0.02	0.522	-0.052
		0.402	*5.036*	*6.924*	*1.071*

Equation 3

	r2	k	dat	ln(f1/f2)	wdfs
EA	0.669	0.57	-0.024	2.863	-0.035
		0.355	*2.404*	*4.34*	*0.358*
EM	0.519	-0.96	-0.016	3.509	0.08
		0.454	*0.979*	*3.055*	*0.618*
GL	0.504	1.064	-0.023	2.104	-0.174
		0.473	*0.941*	*1.918*	*1.116*
N	0.27	0.235	-0.014	0.579	0.112
		0.16	*1.303*	*0.774*	*1.212*
NW	0.367	0.395	-0.02	2.839	-0.036
		0.152	*1.364*	*2.543*	*0.228*
SE	0.804	0.748	-0.055	1.661	0.094
		0.469	*3.173*	*1.918*	*0.826*
SW	0.743	-0.043	-0.003	3.086	-0.179
		0.03	*0.261*	*5.348*	*1.962*
WM	0.348	-0.864	-0.013	2.423	-0.155
		0.363	*0.782*	*2.239*	*1.067*
Y	0.595	0.058	-0.019	4.291	-0.064
		0.026	*1.211*	*3.797*	*0.456*
ALL	0.463	0.257	-0.024	2.88	-0.052
		0.366	*6.71*	*9.9*	*1.208*

Equation 4

	r2	k	dat	dfq	dfs
EA	0.435	3.511	-0.029	0.015	0.064
		2.063	*2.136*	*1.051*	*1.555*
EM	0.773	1.404	-0.015	0.025	0.12
		1.014	*1.444*	*2.493*	*3.736*
GL	0.347	3.064	-0.045	0.011	0.002
		1.391	*1.82*	*0.539*	*0.032*
N	0.257	0.213	-0.016	-0.001	0.04
		0.147	*1.768*	*0.057*	*1.361*
NW	0.337	2.302	-0.009	0.018	0.067
		0.922	*0.613*	*0.961*	*1.352*
SE	0.74	0.768	-0.062	0.006	0.04
		0.464	*4.381*	*0.436*	*1.252*
SW	0.463	3.747	0.001	0.029	0.043
		2.233	*0.049*	*1.946*	*1.16*
WM	0.311	3.475	-0.005	0.009	0.075
		1.576	*0.291*	*0.532*	*1.637*
Y	0.567	1.179	0.001	0.043	0.047
		0.535	*0.066*	*2.746*	*1.072*
ALL	0.374	3.155	-0.021	0.019	0.061
		4.905	*5.539*	*3.499*	*4.23*

Equation 5

	r2	k	dat	f1/f2	dfs
EA	0.467	2.801	-0.028	0.326	0.049
		1.498	*2.071*	*1.353*	*1.103*
EM	0.709	1.873	-0.018	0.305	0.125
		1.15	*1.503*	*1.566*	*3.366*
GL	0.353	2.76	-0.044	0.217	-0.007
		1.143	*1.777*	*0.624*	*0.118*
N	0.262	-0.093	-0.017	0.048	0.035
		0.062	*1.795*	*0.274*	*1.149*
NW	0.348	1.979	-0.011	0.337	0.055
		0.765	*0.792*	*1.063*	*1.026*
SE	0.747	0.486	-0.06	0.152	0.032
		0.271	*4.217*	*0.697*	*0.944*
SW	0.453	3.626	-0.007	0.42	0.037
		1.929	*0.382*	*1.722*	*0.891*
WM	0.306	3.453	-0.006	0.142	0.073
		1.487	*0.375*	*0.491*	*1.485*
Y	0.503	1.491	-0.004	0.617	0.044
		0.596	*0.26*	*2.101*	*0.87*
ALL	0.363	2.695	-0.023	0.341	0.051
		3.82	*5.693*	*3.792*	*3.265*

Equation 6

	r2	k	dat	ln(f1/f2)	dfs
EA	0.666	0.994	-0.024	2.868	-0.001
		0.649	*2.18*	*3.074*	*0.03*
EM	0.744	1.68	-0.026	1.991	0.115
		1.149	*2.116*	*2.074*	*3.226*
GL	0.548	0.836	-0.013	3.825	-0.091
		0.414	*0.546*	*2.302*	*1.56*
N	0.258	0.062	-0.017	0.116	0.037
		0.044	*1.641*	*0.124*	*1.125*
NW	0.395	1.564	-0.017	2.281	0.027
		0.647	*1.19*	*1.437*	*0.446*
SE	0.792	-0.044	-0.047	1.96	0.001
		0.029	*3.049*	*1.728*	*0.026*
SW	0.654	2.157	-0.011	3.076	-0.005
		1.423	*0.794*	*3.327*	*0.126*
WM	0.343	2.86	-0.011	1.335	0.054
		1.294	*0.656*	*0.916*	*1.022*
Y	0.591	1.34	-0.018	3.919	0.016
		0.623	*1.136*	*2.779*	*0.311*
ALL	0.482	1.448	-0.025	2.583	0.016
		2.215	*6.778*	*6.478*	*1.004*

Ratio of Access Time

Equation 1

	r2	k	ret	dfq	wdfe
EA	0.547	-2.298	0.418	0.039	0.065
		0.887	*0.916*	*2.97*	*0.457*
EM	0.402	9.174	-7.337	0.003	-0.161
		2.062	*1.806*	*0.156*	*1.034*
GL	0.563	11.582	-10.29	-0.116	0.19
		3.677	*2.858*	*2.189*	*2.353*
N	0.309	2.69	-2.201	0.007	0.127
		1.157	*1.492*	*0.756*	*1.448*
NW	0.467	2.2	-1.405	0.026	-0.145
		0.916	*2.391*	*1.747*	*0.835*
SE	0.799	15.715	-15.442	-0.001	0.091
		5.603	*5.557*	*0.088*	*0.935*
SW	0.503	-1.186	1.732	0.037	-0.154
		0.376	*0.835*	*3.029*	*1.245*
WM	0.23	1.24	-0.579	0.023	-0.099
		0.402	*0.863*	*1.432*	*0.625*
Y	0.54	0.667	-0.154	0.053	0.043
		0.239	*0.141*	*3.548*	*0.292*
ALL	0.246	2.157	-0.8	0.03	-0.011
		2.342	*3.137*	*5.796*	*0.203*

Equation 2

	r2	k	ret	f1/f2	wdfe
EA	0.466	4.426	-2.835	0.439	-0.047
		1.679	*2.062*	*2.285*	*0.374*
EM	0.423	-1.808	0.122	0.568	0.05
		0.619	*0.205*	*2.133*	*0.31*
GL	0.417	7.959	-6.578	0.157	-0.176
		1.792	*1.732*	*0.569*	*1.13*
N	0.336	2.851	-2.61	0.148	0.112
		1.25	*1.685*	*1.024*	*1.286*
NW	0.557	1.266	-1.51	0.478	-0.205
		0.541	*2.794*	*2.295*	*1.277*
SE	0.804	14.472	-14.452	0.09	0.076
		4.73	*5.06*	*0.509*	*0.76*
SW	0.535	-1.622	1.289	0.583	-0.204
		0.527	*0.646*	*3.253*	*1.702*
WM	0.307	0.612	-0.707	0.436	-0.135
		0.205	*1.087*	*1.867*	*0.892*
Y	0.498	0.703	-0.939	0.829	-0.054
		0.234	*0.774*	*3.259*	*0.344*
ALL	0.29	1.416	-0.95	0.519	-0.059
		1.535	*3.817*	*6.623*	*1.156*

Equation 3

	r2	k	ret	ln(f1/f2)	wdfe
EA	0.703	4.087	-2.842	2.633	-0.05
		2.13	*2.773*	*4.265*	*0.536*
EM	0.478	-0.913	-0.069	2.845	0.078
		0.326	*0.117*	*2.489*	*0.507*
GL	0.498	4.633	-3.587	1.883	-0.206
		1.006	*0.872*	*1.466*	*1.414*
N	0.336	3.473	-3.044	0.729	0.11
		1.454	*1.722*	*1.023*	*1.254*
NW	0.68	1.321	-1.703	2.598	-0.236
		0.695	*3.697*	*3.396*	*1.725*
SE	0.806	13.028	12.907	0.781	0.056
		3.21	*3.245*	*0.737*	*0.53*
SW	0.742	-0.483	0.301	3.064	0.19
		0.219	*0.201*	*5.287*	*2.145*
WM	0.471	1.311	-1.065	2.604	-0.127
		0.523	*1.619*	*2.828*	*0.969*
Y	0.667	2.63	-2.236	4.598	-0.064
		1.089	*2.04*	*4.648*	*0.658*
ALL	0.415	1.613	-1.126	2.796	-0.059
		1.992	*4.941*	*9.012*	*1.28*

Equation 4

	r2	k	ret	dfq	dfe
EA	0.695	4.671	-2.816	2.634	-0.001
		2.06	*2.509*	*2.91*	*0.036*
EM	0.772	2.783	-0.636	0.022	0.139
		1.336	*1.421*	*2.148*	*3.351*
GL	0.347	3.084	-0.045	0.011	0.002
		1.391	*1.82*	*0.539*	*0.032*
N	0.257	0.213	-0.016	-0.001	0.04
		0.147	*1.768*	*0.058*	*1.381*
NW	0.337	2.302	-0.009	0.018	0.067
		0.922	*0.613*	*0.961*	*1.352*
SE	0.74	0.768	-0.062	0.006	0.04
		0.464	*4.381*	*0.438*	*1.252*
SW	0.483	3.747	0.001	0.029	0.043
		2.233	*0.049*	*1.946*	*1.15*
WM	0.311	3.475	-0.005	0.009	0.075
		1.576	*0.291*	*0.532*	*1.637*
Y	0.567	1.179	0.001	0.043	0.047
		0.535	*0.066*	*2.746*	*1.072*
ALL	0.313	4.036	-0.936	0.021	0.054
		5.076	*3.803*	*3.625*	*3.584*

Equation 5

	r2	k	ret	f1/f2	dfe
EA	0.518	7.233	-3.378	0.265	0.048
		2.649	*2.429*	*1.137*	*1.156*
EM	0.75	3.836	-0.976	0.327	0.156
		1.944	*2.098*	*1.801*	*3.819*
GL	0.361	10.077	-7.201	0.192	-0.023
		2.359	*1.83*	*0.548*	*0.442*
N	0.339	3.714	-3.505	0.064	0.036
		1.433	*2.206*	*0.365*	*1.302*
NW	0.504	3.443	-1.056	0.376	0.026
		1.458	*2.068*	*1.363*	*0.528*
SE	0.793	12.847	-13.665	0.13	-0.001
		5.466	*4.925*	*0.66*	*0.023*
SW	0.449	2.99	0.535	0.433	0.035
		1.044	*0.252*	*1.784*	*0.846*
WM	0.412	5.237	-0.868	0.158	0.077
		2.11	*1.448*	*0.597*	*1.703*
Y	0.536	3.344	-1.11	0.656	0.051
		1.074	*0.952*	*2.308*	*1.043*
ALL	0.32	3.688	-1.013	0.362	0.043
		4.414	*4.136*	*3.82*	*2.668*

Equation 6

	r2	k	ret	ln(f1/f2)	dfe
EA	0.666	0.994	-0.024	2.868	-0.001
		0.649	*2.18*	*3.074*	*0.03*
EM	0.729	3.873	-0.909	1.319	0.149
		1.83	*1.892*	*1.463*	*3.264*
GL	0.536	2.073	-1.178	4.054	-0.1
		0.408	*0.268*	*2.153*	*1.768*
N	0.334	3.936	-3.589	0.23	0.039
		1.55	*2.061*	*0.262*	*1.234*
NW	0.599	2.794	-1.359	2.82	-0.02
		1.374	*2.783*	*2.216*	*0.386*
SE	0.806	10.636	-11.601	1.328	-0.014
		3.333	*3.285*	*1.1*	*0.408*
SW	0.636	2.5	-0.403	3.109	-0.006
		1.131	*0.231*	*3.234*	*0.167*
WM	0.477	4.555	-1.066	1.679	0.049
		2.065	*1.832*	*1.334*	*1.036*
Y	0.657	3.947	-2.07	4.215	0.015
		1.547	*1.914*	*3.316*	*0.325*
ALL	0.409	2.704	-1.13	2.584	0.01
		3.496	*4.923*	*6.055*	*0.593*

Difference in Access Time

LEISURE OTHER PAX UK SHORT HAUL MODEL

Equation 1

	r2	k	det	dfq	wdfe
EA	0.436	0.963	-0.013	0.012	-0.099
		0.887	*1.946*	*1.674*	*1.441*
EM	0.53	-0.398	0.006	0.015	0.015
		0.468	*1.256*	*2.752*	*0.288*
GL	0.35	1.423	-0.022	0.01	-0.129
		0.756	*1.17*	*0.81*	*1.023*
N	0.579	0.04	0.016	0.018	0.114
		0.033	*2.313*	*2.382*	*1.543*
NW	0.36	0.498	-0.009	0.023	0.071
		0.281	*0.911*	*2.128*	*0.621*
SE	0.492	0.600	-0.011	0.01	-0.069
		0.646	*1.331*	*1.512*	*1.083*
SW	0.567	1.383	-0.064	0.018	-0.038
		0.565	*2.914*	*1.174*	*0.253*
WM	0.339	-0.217	-0.015	0.019	-0.03
		0.133	*1.494*	*1.924*	*0.304*
Y	0.388	-0.247	0.01	0.027	0.099
		0.128	*0.846*	*2.216*	*0.823*
ALL	0.283	0.541	-0.013	0.02	-0.028
		0.948	*4.433*	*5.59*	*0.787*

Equation 2

	r2	k	det	f1/f2	wdfe
EA	0.475	0.58	-0.013	0.199	-0.117
		0.521	*2.031*	*1.951*	*1.77*
EM	0.452	-0.572	0.005	0.215	-0.004
		0.6	*0.789*	*2.217*	*0.077*
GL	0.353	1.155	-0.021	0.168	-0.146
		0.583	*1.125*	*0.843*	*1.135*
N	0.574	-0.282	0.013	0.288	0.081
		0.226	*1.7*	*2.342*	*1.084*
NW	0.413	-0.073	-0.013	0.384	0.019
		0.041	*1.405*	*2.439*	*0.173*
SE	0.465	0.488	-0.01	0.136	-0.086
		0.469	*1.094*	*1.27*	*1.253*
SW	0.598	0.771	-0.067	0.328	-0.06
		0.315	*3.273*	*1.525*	*0.411*
WM	0.362	-0.668	-0.019	0.331	-0.061
		0.41	*1.892*	*2.178*	*0.635*
Y	0.382	-0.734	0.004	0.436	0.049
		0.363	*0.361*	*2.185*	*0.4*
ALL	0.312	-0.026	-0.015	0.333	-0.059
		0.044	*5.043*	*6.167*	*1.678*

Equation 3

	r2	k	det	ln(f1/f2)	wdfe
EA	0.627	0.452	-0.014	1.164	-0.118
		0.499	*2.521*	*3.136*	*2.117*
EM	0.526	-0.363	-0.001	1.26	0.001
		0.449	*0.18*	*2.722*	*0.025*
GL	0.47	0.819	-0.01	1.503	-0.179
		0.473	*0.579*	*1.814*	*1.524*
N	0.599	0.001	0.007	1.511	0.073
		0.001	*0.81*	*2.545*	*0.992*
NW	0.504	0.172	-0.018	2.014	0.001
		0.11	*2.064*	*3.009*	*0.009*
SE	0.622	0.353	0.001	1.217	-0.129
		0.435	*0.095*	*2.614*	*2.11*
SW	0.659	0.756	-0.071	1.84	-0.052
		0.352	*3.798*	*2.176*	*0.388*
WM	0.495	-0.446	-0.026	1.848	-0.062
		0.316	*2.667*	*2.874*	*0.715*
Y	0.42	-0.326	-0.005	2.301	0.034
		0.173	*0.346*	*2.407*	*0.284*
ALL	0.405	-0.003	-0.017	1.762	-0.058
		0.005	*6.21*	*8.04*	*1.78*

Equation 4

	r2	k	det	dfq	dfe
EA	0.349	1.814	-0.012	0.014	-0.003
		1.87	*1.548*	*1.729*	*0.569*
EM	0.705	0.654	0	0.01	0.038
		1.021	*0.084*	*2.142*	*2.578*
GL	0.304	2.297	-0.026	0.013	-0.019
		1.373	*1.394*	*0.859*	*0.501*
N	0.631	0.307	0.009	0.01	0.045
		0.28	*1.316*	*1.335*	*2.06*
NW	0.478	1.229	-0.011	0.013	0.05
		0.83	*1.302*	*1.206*	*1.708*
SE	0.472	0.78	-0.016	0.011	-0.015
		0.855	*1.968*	*1.593*	*0.84*
SW	0.679	4.111	-0.073	0.002	0.075
		2.43	*3.967*	*0.154*	*1.986*
WM	0.534	1.949	-0.02	0.01	0.056
		1.594	*2.264*	*1.008*	*2.18*
Y	0.537	1.051	0	0.015	0.07
		0.638	*0.015*	*1.333*	*2.105*
ALL	0.342	1.975	-0.015	0.013	0.037
		4.265	*5.292*	*3.442*	*3.531*

Equation 5

	r2	k	det	f1/f2	dfe
EA	0.371	1.438	-0.011	0.259	-0.023
		1.333	*1.425*	*1.862*	*0.892*
EM	0.642	0.851	-0.002	0.119	0.041
		1.16	*0.285*	*1.36*	*2.42*
GL	0.297	2.131	-0.026	0.207	-0.023
		1.159	*1.407*	*0.782*	*0.549*
N	0.636	0.187	0.008	0.185	0.041
		0.167	*1.088*	*1.407*	*1.8*
NW	0.49	0.965	-0.013	0.251	0.041
		0.646	*1.535*	*1.343*	*1.303*
SE	0.422	0.793	-0.016	0.149	-0.016
		0.788	*1.9*	*1.168*	*0.794*
SW	0.661	3.906	-0.073	0.065	0.071
		2.126	*4.217*	*0.272*	*1.753*
WM	0.525	1.959	-0.021	0.143	0.054
		1.51	*2.404*	*0.888*	*1.958*
Y	0.526	1.039	-0.002	0.248	0.066
		0.604	*0.173*	*1.222*	*1.883*
ALL	0.337	1.81	-0.016	0.216	0.032
		3.524	*5.564*	*3.292*	*2.832*

Equation 6

	r2	k	det	ln(f1/f2)	dfe
EA	0.684	0.332	-0.008	2.025	-0.055
		0.419	*1.47*	*4.217*	*2.696*
EM	0.675	0.776	-0.005	0.778	0.037
		1.159	*0.825*	*1.769*	*2.24*
GL	0.552	0.598	-0.001	3.247	-0.092
		0.405	*0.075*	*2.686*	*2.18*
N	0.637	0.309	0.004	0.988	0.037
		0.291	*0.577*	*1.418*	*1.503*
NW	0.525	0.83	-0.017	1.549	0.024
		0.581	*1.947*	*1.65*	*0.685*
SE	0.632	0.422	-0.005	1.693	-0.042
		0.548	*0.625*	*2.9*	*2.207*
SW	0.696	3.151	-0.074	0.877	0.054
		1.733	*4.401*	*0.79*	*1.221*
WM	0.556	1.697	-0.025	1.028	0.043
		1.385	*2.697*	*1.272*	*1.449*
Y	0.526	1.216	-0.006	1.303	0.061
		0.742	*0.507*	*1.213*	*1.595*
ALL	0.397	1.188	-0.017	1.504	0.013
		2.399	*6.266*	*4.978*	*1.127*

Ratio of Access Time

Equation 1

	r2	k	ret	dfq	wdfe
EA	0.537	3.119	-1.8	0.01	-0.109
		2.505	*2.646*	*1.661*	*1.767*
EM	0.569	-1.224	0.297	0.014	-0.019
		1.193	*1.645*	*2.725*	*0.344*
GL	0.376	5.476	-4.162	0.005	-0.161
		1.65	*1.373*	*0.34*	*1.385*
N	0.526	-2.454	2.451	0.016	0.107
		1.191	*1.674*	*2.261*	*1.371*
NW	0.619	1.222	-1.008	0.02	-0.061
		0.886	*2.984*	*2.331*	*0.615*
SE	0.532	3.176	-2.775	0.007	-0.078
		1.919	*1.693*	*1.047*	*1.362*
SW	0.424	5.429	-5.454	0.026	-0.108
		1.249	*1.909*	*1.565*	*0.633*
WM	0.432	1.328	-0.828	0.019	-0.007
		0.743	*2.1*	*2.079*	*0.08*
Y	0.353	-0.295	0.258	0.028	0.089
		0.122	*0.282*	*2.272*	*0.723*
ALL	0.278	1.454	-0.758	0.02	-0.032
		2.298	*4.327*	*5.633*	*0.892*

Equation 2

	r2	k	ret	f1/f2	wdfe
EA	0.555	2.755	-1.743	0.169	-0.125
		2.155	*2.614*	*1.816*	*2.059*
EM	0.456	-1.047	0.199	0.2	-0.026
		0.91	*0.848*	*1.9*	*0.407*
GL	0.387	5.009	-3.955	0.113	-0.172
		1.504	*1.369*	*0.547*	*1.466*
N	0.532	-2.097	1.775	0.303	0.074
		1.023	*1.275*	*2.325*	*0.943*
NW	0.677	0.63	-1.09	0.343	-0.106
		0.472	*3.54*	*2.887*	*1.163*
SE	0.521	3.078	-2.792	0.096	-0.088
		1.666	*1.619*	*0.901*	*1.456*
SW	0.422	5.218	5.774	0.397	0.142
		1.187	*2.026*	*1.551*	*0.832*
WM	0.45	1.028	-0.907	0.306	-0.034
		0.574	*2.321*	*2.198*	*0.38*
Y	0.379	-0.361	0.235	0.483	0.034
		0.153	*0.246*	*2.416*	*0.275*
ALL	0.307	1.000	-0.855	0.337	-0.063
		1.562	*4.95*	*6.21*	*1.807*

Equation 3

	r2	k	ret	ln(f1/f2)	wdfe
EA	0.689	2.607	-1.746	1.033	-0.127
		2.497	*3.131*	*3.076*	*2.494*
EM	0.534	-0.706	0.106	1.078	-0.013
		0.656	*0.467*	*2.458*	*0.219*
GL	0.469	2.537	-1.738	1.385	-0.194
		0.733	*0.562*	*1.434*	*1.767*
N	0.582	-0.672	0.659	1.642	0.066
		0.331	*0.439*	*2.715*	*0.865*
NW	0.772	0.776	-1.222	1.747	-0.127
		0.727	*-4.714*	*4.058*	*1.642*
SE	0.622	0.528	-0.185	1.145	-0.123
		0.239	*0.086*	*1.988*	*2.142*
SW	0.479	6.000	-6.444	2.069	-0.133
		1.492	*2.369*	*1.967*	*0.823*
WM	0.55	1.594	-1.133	1.654	-0.029
		1.022	*3.052*	*2.886*	*0.348*
Y	0.456	0.755	-0.919	2.565	0.019
		0.346	*0.929*	*2.871*	*0.163*
ALL	0.39	1.163	-0.96	1.739	-0.063
		2.038	*6.871*	*7.852*	*1.909*

Equation 4

	r2	k	ret	dfq	dfe
EA	0.429	3.86	-1.629	0.014	-0.014
		2.752	*2.068*	*1.723*	*0.674*
EM	0.712	1.022	-0.103	0.01	0.045
		1.075	*0.505*	*2.018*	*2.369*
GL	0.3	6.903	-4.389	0.01	-0.028
		2.097	*1.368*	*0.591*	*0.718*
N	0.604	-0.735	1.209	0.01	0.048
		0.335	*0.936*	*1.288*	*2.101*
NW	0.647	2.147	-0.799	0.016	0.028
		1.717	*2.802*	*1.688*	*1.129*
SE	0.531	4.357	-3.963	0.009	-0.023
		3.343	*2.419*	*1.297*	*1.354*
SW	0.458	8.807	-6.016	0.017	0.051
		2.428	*2.219*	*0.925*	*1.064*
WM	0.615	3.205	-0.957	0.01	0.052
		2.441	*2.932*	*1.139*	*2.284*
Y	0.55	2.064	-0.457	0.015	0.076
		0.939	*0.573*	*1.367*	*2.363*
ALL	0.326	2.927	-0.843	0.014	0.033
		5.293	*4.921*	*3.644*	*3.179*

Equation 5

	r2	k	ret	f1/f2	dfe
EA	0.427	3.383	-1.464	0.23	-0.022
		2.14	*1.818*	*1.705*	*0.917*
EM	0.678	1.511	-0.246	0.132	0.053
		1.661	*1.146*	*1.582*	*2.802*
GL	0.309	6.641	-4.449	0.187	-0.033
		2.046	*1.488*	*0.704*	*0.824*
N	0.614	-0.552	0.898	0.192	0.044
		0.261	*0.691*	*1.408*	*1.847*
NW	0.653	1.892	-0.835	0.27	0.019
		1.435	*2.93*	*1.75*	*0.708*
SE	0.513	4.426	-4.148	0.128	-0.026
		3.172	*2.518*	*1.094*	*1.378*
SW	0.436	9.37	-6.312	0.192	0.053
		2.526	*2.297*	*0.612*	*0.988*
WM	0.597	3.334	-0.99	0.128	0.052
		2.405	*2.957*	*0.863*	*2.044*
Y	0.551	2.15	-0.645	0.272	0.071
		0.99	*0.794*	*1.373*	*2.078*
ALL	0.321	2.804	-0.895	0.233	0.028
		4.785	*5.208*	*3.505*	*2.45*

Equation 6

	r2	k	ret	ln(f1/f2)	dfe
EA	0.717	1.806	-1.104	1.919	-0.054
		1.555	*1.92*	*4.139*	*2.813*
EM	0.688	1.371	-0.226	0.671	0.047
		1.487	*1.082*	*1.709*	*2.342*
GL	0.553	-0.117	0.672	3.524	-0.098
		0.032	*0.213*	*2.603*	*2.405*
N	0.628	0.114	0.287	1.103	0.037
		0.056	*0.206*	*1.569*	*1.493*
NW	0.718	1.652	-1.02	1.789	-0.007
		1.452	*3.731*	*2.513*	*0.224*
SE	0.645	1.952	-1.683	1.515	-0.042
		1.147	*0.91*	*2.398*	*2.372*
SW	0.462	9.088	-6.747	1.443	0.033
		2.643	*2.482*	*0.965*	*0.559*
WM	0.623	3.212	-1.1	0.901	0.041
		2.54	*3.237*	*1.249*	*1.507*
Y	0.564	2.517	-0.967	1.531	0.061
		1.238	*1.122*	*1.511*	*1.66*
ALL	0.377	2.321	-0.962	1.539	0.01
		4.16	*5.813*	*5.000*	*0.806*

Appendix C Difference in Access Time

LEISURE IT PAX UK CHARTER MODEL

Equation 1

	r2	k	dat	dfq	wdfe
EA	0.81	0.158	-0.049	0.008	-0.057
		0.286	*4.367*	*4.23*	*2.71*
EM	0.825	-0.718	0	-0.001	-0.035
		2.001	*0.079*	*0.277*	*2.221*
GL	0.354	3.647	-0.021	0.009	0.042
		1.701	*0.729*	*1.608*	*0.766*
N	0.761	-1.069	-0.006	0.006	-0.025
		1.306	*0.749*	*1.648*	*1.024*
NW	0.774	-0.79	-0.012	0.009	-0.017
		0.652	*1.213*	*2.186*	*0.462*
SE	0.657	1.084	-0.007	0.003	-0.001
		2.074	*1.302*	*1.986*	*0.096*
SW	0.855	1.315	-0.032	0.01	0.035
		2.777	*2.661*	*3.089*	*1.23*
WM	0.745	-0.457	-0.019	0.005	-0.029
		0.364	*1.194*	*0.703*	*0.626*
Y	0.78	-0.819	-0.01	0.007	-0.018
		1.037	*1.318*	*1.966*	*0.77*
ALL	0.581	0.727	-0.022	0.008	0.004
		3.026	*8.801*	*6.468*	*0.436*

Equation 2

	r2	k	dat	f1/f2	wdfe
EA	0.343	0.623	-0.025	0.287	-0.026
		0.469	*1.362*	*0.946*	*0.726*
EM	0.84	-0.775	-0.003	0.12	-0.024
		2.776	*0.964*	*0.808*	*2.628*
GL	0.111	3.014	-0.019	0.333	0.013
		1.09	*0.568*	*0.488*	*0.201*
N	0.77	-2.184	-0.004	0.499	-0.027
		3.266	*0.666*	*1.662*	*1.232*
NW	0.746	-2.748	-0.008	0.781	-0.027
		2.034	*0.83*	*1.894*	*0.733*
SE	0.467	0.639	-0.009	0.13	-0.012
		0.988	*1.381*	*0.632*	*0.733*
SW	0.743	-0.106	-0.009	0.419	-0.014
		0.182	*0.906*	*1.662*	*0.604*
WM	0.789	-1.497	-0.017	0.467	-0.028
		2.024	*1.936*	*1.369*	*1.042*
Y	0.759	-2.102	-0.006	0.529	-0.024
		3.022	*0.941*	*1.728*	*1.072*
ALL	0.496	-0.437	-0.019	0.569	-0.006
		1.367	*7.207*	*4.486*	*0.694*

Equation 3

	r2	k	dat	ln(f1/f2)	wdfe
EA	0.851	0.092	-0.062	2.326	-0.058
		0.186	*6.213*	*4.928*	*3.113*
EM	0.823	-0.645	-0.001	-0.005	-0.031
		1.679	*0.228*	*0.009*	*1.868*
GL	0.327	3.735	-0.026	2.188	0.051
		1.706	*0.892*	*1.498*	*0.846*
N	0.767	-0.958	-0.004	1.239	-0.018
		1.144	*0.611*	*1.632*	*0.666*
NW	0.774	-0.761	-0.009	2.067	-0.008
		0.63	*0.965*	*2.188*	*0.2*
SE	0.832	1.116	-0.008	0.726	0.002
		2.026	*1.67*	*1.803*	*0.16*
SW	0.764	1.401	-0.203	1.708	0.026
		1.976	*1.687*	*1.887*	*0.663*
WM	0.737	-0.638	-0.015	0.666	-0.036
		0.489	*1.127*	*0.624*	*0.746*
Y	0.785	-0.709	-0.008	1.451	-0.01
		0.489	1.127	0.524	0.745
ALL	0.558	1.038	-0.021	1.732	0.014
		3.944	*8.337*	*6.929*	*1.381*

Equation 4

	r2	k	dat	dfq	dfe
EA	0.828	0.105	-0.046	0.007	-0.061
		0.198	*4.836*	*4.276*	*2.948*
EM	0.791	-0.698	-0.002	0	-0.034
		1.664	*0.316*	*0.068*	*1.769*
GL	0.334	3.535	-0.024	0.009	0.04
		1.679	*0.862*	*1.604*	*0.626*
N	0.756	-1.028	-0.007	0.006	-0.027
		1.261	*0.86*	*1.679*	*0.943*
NW	0.774	-0.803	-0.013	0.009	-0.019
		0.66	*1.309*	*2.167*	*0.466*
SE	0.659	1.045	-0.007	0.003	-0.003
		1.96	*1.366*	*1.848*	*0.22*
SW	0.84	1.272	-0.028	0.009	0.028
		2.341	*2.409*	*2.762*	*0.899*
WM	0.742	-0.379	-0.022	0.005	-0.026
		0.291	*1.484*	*0.866*	*0.648*
Y	0.778	-0.834	-0.01	0.007	-0.019
		1.008	*1.418*	*1.976*	*0.724*
ALL	0.581	0.723	-0.022	0.008	0.003
		2.856	*8.781*	*6.2*	*0.298*

Equation 5

	r2	k	dat	f1/f2	dfe
EA	0.408	0.301	-0.029	0.29	-0.042
		0.237	*1.763*	*1.028*	*1.112*
EM	0.82	-0.868	-0.004	0.152	-0.026
		3.016	*1.208*	*0.99*	*2.233*
GL	0.105	2.866	-0.023	0.264	0.002
		1.026	*0.692*	*0.378*	*0.021*
N	0.768	-2.245	-0.004	0.512	-0.03
		3.331	*0.673*	*1.714*	*1.199*
NW	0.748	-2.783	-0.009	0.772	-0.031
		2.066	*0.92*	*1.887*	*0.769*
SE	0.489	0.609	-0.009	0.106	-0.017
		0.968	*1.46*	*0.623*	*0.9*
SW	0.749	-0.141	-0.009	0.4	-0.018
		0.26	*0.967*	*1.629*	*0.723*
WM	0.786	-1.555	-0.018	0.492	-0.029
		2.082	*2.172*	*1.466*	*0.989*
Y	0.759	2.155	-0.007	0.534	-0.027
		3.1	*1.048*	*1.769*	*1.076*
ALL	0.498	-0.44	-0.018	0.532	-0.01
		1.393	*7.221*	*4.233*	*0.878*

Equation 6

	r2	k	dat	ln(f1/f2)	dfe
EA	0.862	0.058	-0.057	2.093	-0.062
		0.122	*6.69*	*4.933*	*3.32*
EM	0.794	-0.603	-0.003	0.182	-0.029
		1.376	*0.629*	*0.333*	*1.496*
GL	0.301	3.618	-0.03	2.115	0.048
		1.673	*1.013*	*1.368*	*0.684*
N	0.765	-0.951	-0.005	1.265	-0.018
		1.078	*0.718*	*1.686*	*0.692*
NW	0.774	-0.766	-0.009	2.067	-0.009
		0.622	*1.033*	*2.161*	*0.196*
SE	0.63	1.074	-0.009	0.678	0
		1.878	*1.638*	*1.634*	*0.001*
SW	0.753	1.263	-0.019	1.446	0.016
		1.626	*1.434*	*1.671*	*0.366*
WM	0.731	-0.547	-0.017	0.831	-0.033
		0.413	*1.44*	*0.694*	*0.661*
Y	0.784	-0.709	-0.008	1.473	-0.011
		0.836	*1.264*	*2.046*	*0.361*
ALL	0.555	1.048	-0.021	1.665	0.014
		3.671	*8.267*	*6.689*	*1.128*

Ratio of Access Time

Equation 1

	r2	k	rwt	dfq	wdfa
EA	0.563	4.524	-2.514	0.003	-0.019
		4.096	*2.196*	*1.448*	*0.762*
EM	0.875	-1.116	0.177	-0.002	-0.043
		3.384	*1.554*	*1.655*	*4.783*
GL	0.343	7.068	-3.091	0.008	0.034
		1.971	*0.646*	*1.304*	*0.532*
N	0.765	0.055	-1.081	0.005	-0.025
		0.027	*0.816*	*1.635*	*1.063*
NW	0.83	-0.211	-0.577	0.006	-0.033
		0.172	*1.989*	*1.895*	*1.334*
SE	0.621	2.348	-1.15	0.003	-0.001
		2.811	*0.985*	*1.545*	*0.092*
SW	0.918	6.186	-4.564	0.009	0.03
		4.367	*4.119*	*4.578*	*1.71*
WM	0.815	0.979	-0.977	0.006	-0.022
		0.673	*2.059*	*1.222*	*0.69*
Y	0.796	-0.027	-0.755	0.006	-0.02
		0.024	*1.526*	*2.128*	*0.99*
ALL	0.475	1.942	-1.018	0.006	-0.002
		5.199	*6.661*	*4.579*	*0.22*

Equation 2

	r2	k	rwt	f1/f2	wdfa
EA	0.573	4.598	-3.319	0.347	-0.03
		4.176	*2.469*	*1.617*	*1.264*
EA	0.818	-0.731	0.027	-0.007	-0.031
		2.432	*0.271*	*0.066*	*3.39*
GL	0.166	7.695	-4.587	0.179	-0.009
		1.716	*0.869*	*0.26*	*0.124*
N	0.767	-1.664	-0.503	0.46	-0.029
		1.112	*0.467*	*1.664*	*1.391*
NW	0.818	-1.347	-0.554	0.555	-0.034
		0.929	*1.834*	*1.721*	*1.312*
SE	0.472	2.817	-2.017	0.029	-0.016
		2.163	*1.407*	*0.123*	*0.917*
SW	0.773	1.627	-1.61	0.443	-0.012
		1.141	*1.31*	*1.936*	*0.681*
WM	0.822	-0.545	-0.666	0.375	-0.035
		0.637	*2.368*	*1.339*	*1.662*
Y	0.757	-1.557	-0.433	0.447	-0.028
		1.603	*0.923*	*1.694*	*1.369*
ALL	0.416	0.933	-0.899	0.409	-0.01
		2.262	*6.747*	*3.171*	*1.009*

Equation 3

	r2	k	rwt	ln(f1/f2)	wdfa
EA	0.533	4.718	-2.598	0.625	-0.018
		3.932	*2.149*	*1.259*	*0.64*
EM	0.858	-1.139	0.147	-0.489	-0.045
		2.832	*1.235*	*1.288*	*3.697*
GL	0.317	8.027	-3.951	1.756	0.037
		2.259	*0.835*	*1.19*	*0.535*
N	0.772	-0.11	-0.803	1.237	-0.018
		0.058	*0.681*	*1.712*	*0.675*
NW	0.824	-0.164	-0.513	1.406	-0.024
		0.132	*1.703*	*1.804*	*0.839*
SE	0.592	2.663	-1.457	0.612	0.001
		3.336	*1.282*	*1.335*	*0.038*
SW	0.846	5.932	-4.055	1.998	0.037
		2.868	*2.65*	*2.894*	*1.246*
WM	0.813	1.051	-0.918	1.225	-0.016
		0.681	*2.055*	*1.178*	*0.426*
Y	0.8	-0.028	-0.628	1.351	-0.012
		0.025	*1.378*	*2.176*	*0.523*
ALL	0.46	2.134	-0.986	1.301	0.006
		5.373	*6.411*	*4.229*	*0.512*

Equation 4

	r2	k	rwt	dfq	dfa
EA	0.586	4.508	-2.6	0.003	-0.026
		4.637	*2.496*	*1.326*	*0.979*
EM	0.834	-1.255	0.175	-0.003	-0.05
		3.033	*1.309*	*1.46*	*3.97*
GL	0.327	7.581	-3.735	0.008	0.028
		2.239	*0.811*	*1.172*	*0.376*
N	0.759	0.153	-1.197	0.006	-0.027
		0.076	*0.917*	*1.646*	*0.981*
NW	0.831	-0.267	-0.595	0.006	-0.039
		0.216	*2.086*	*1.768*	*1.362*
SE	0.624	2.364	-1.215	0.003	-0.004
		2.916	*1.063*	*1.416*	*0.229*
SW	0.907	5.847	-4.23	0.009	0.029
		3.931	*3.781*	*4.086*	*1.373*
WM	0.811	1.066	-1.035	0.006	-0.021
		0.734	*2.288*	*1.328*	*0.686*
Y	0.792	-0.026	-0.785	0.006	-0.022
		0.022	*1.608*	*2.091*	*0.936*
ALL	0.475	1.917	-1.015	0.006	-0.004
		4.949	*6.668*	*4.363*	*0.317*

Equation 5

	r2	k	rwt	f1/f2	dfa
EA	0.607	4.618	-3.316	0.322	-0.036
		4.786	*2.77*	*1.476*	*1.493*
EM	0.776	-0.815	0.012	0.009	-0.034
		2.462	*0.11*	*0.062*	*2.868*
GL	0.176	8.097	-5.122	0.096	-0.024
		1.97	*1.019*	*0.14*	*0.302*
N	0.763	-1.62	-0.609	0.47	-0.032
		1.079	*0.564*	*1.684*	*1.346*
NW	0.823	-1.373	-0.57	0.53	-0.04
		0.968	*1.934*	*1.627*	*1.383*
SE	0.499	2.799	-2.04	0.004	-0.021
		2.314	*1.603*	*0.016*	*1.096*
SW	0.778	1.558	-1.573	0.423	-0.016
		1.119	*1.363*	*1.879*	*0.707*
WM	0.816	-0.571	-0.728	0.395	-0.037
		0.651	*2.638*	*1.394*	*1.461*
Y	0.756	-1.58	-0.466	0.446	-0.032
		1.618	*1.014*	*1.684*	*1.367*
ALL	0.419	0.909	-0.896	0.386	-0.014
		2.22	*6.767*	*2.962*	*1.223*

Equation 6

	r2	k	rwt	ln(f1/f2)	dfa
EA	0.558	4.698	-2.694	0.557	-0.024
		4.376	*2.44*	*1.122*	*0.876*
EM	0.806	-1.215	0.125	-0.445	-0.049
		2.366	*0.893*	*0.965*	*2.91*
GL	0.3	8.487	-4.587	1.605	0.029
		2.604	*1.008*	*1.043*	*0.366*
N	0.769	-0.016	-0.893	1.277	-0.018
		0.009	*0.778*	*1.747*	*0.603*
NW	0.825	-0.213	-0.528	1.352	-0.029
		0.17	*1.773*	*1.666*	*0.866*
SE	0.593	2.673	-1.527	0.55	-0.002
		3.4	*1.376*	*1.18*	*0.126*
SW	0.828	5.265	-3.499	1.775	0.03
		2.612	*2.363*	*2.609*	*0.883*
WM	0.811	1.166	-0.965	1.323	-0.014
		0.767	*2.337*	*1.316*	*0.337*
Y	0.798	-0.018	-0.648	1.365	-0.013
		0.016	*1.466*	*2.161*	*0.484*
ALL	0.459	2.113	-0.978	1.262	0.005
		6.066	*6.38*	*3.971*	*0.336*

Difference in Access Time

LEISURE OTHER PAX UK CHARTER MODEL

Equation 1

	r2	k	dat	dtq	wdfe
EA	0.845	0.34	-0.063	0.012	-0.063
		0.286	*2.596*	*3.067*	*1.399*
EM	0.959	-0.5	0.001	0	-0.047
		2.001	*0.267*	*0.061*	*4.323*
GL	0.394	3.236	-0.022	0.009	0.032
		1.697	*0.865*	*1.786*	*0.668*
N	0.846	0.899	-0.021	0.012	0.011
		0.919	*2.8*	*3.603*	*0.486*
NW	0.648	0.326	-0.012	0.009	0.029
		0.267	*1.407*	*2.623*	*0.926*
SE	0.595	1.654	-0.003	0.006	0.012
		2.243	*0.396*	*2.361*	*0.638*
SW	0.876	1.282	-0.02	0.007	0.007
		2.836	*1.746*	*2.622*	*0.26*
WM	0.817	-0.287	-0.012	0.003	-0.043
		0.283	*0.967*	*0.602*	*1.209*
Y	0.815	0.429	-0.015	0.009	0.012
		0.691	*2.479*	*3.467*	*0.669*
ALL	0.61	0.693	-0.02	-0.013	0.188
		2.416	*9.164*	*1.166*	*1.827*

Equation 2

	r2	k	dat	f1/f2	wdfe
EA	0.162	1.303	-0.023	0.379	-0.013
		0.552	*0.688*	*0.7*	*0.207*
EM	0.964	-0.616	0	0.096	-0.043
		3.237	*0.082*	*0.947*	*6.499*
GL	0.123	2.545	-0.02	0.369	0.006
		1.009	*0.652*	*0.591*	*0.106*
N	0.621	-1.373	-0.009	0.589	-0.022
		1.38	*0.917*	*1.316*	*0.678*
NW	0.451	-1.57	-0.006	0.619	0.007
		1.159	*0.63*	*1.497*	*0.18*
SE	0.296	0.879	-0.006	0.25	-0.005
		0.909	*0.643*	*0.811*	*0.193*
SW	0.805	0.195	-0.002	0.31	-0.032
		0.374	*0.203*	*1.371*	*1.621*
WM	0.845	-0.908	-0.012	0.32	-0.039
		1.547	*1.714*	*1.171*	*1.833*
Y	0.583	-1.18	-0.006	0.486	-0.011
		1.606	*0.841*	*1.406*	*0.437*
ALL	0.446	0.044	-0.016	0.525	-0.004
		0.139	*6.377*	*4.295*	*0.414*

Equation 3

	r2	k	dat	ln(f1/f2)	wdfe
EA	0.701	0.205	-0.063	3.671	-0.065
		0.186	*3.168*	*3.491*	*1.686*
EM	0.96	-0.444	0	0.118	-0.045
		1.679	*0.136*	*0.321*	*3.949*
GL	0.366	3.324	-0.027	2.172	0.042
		1.702	*1.033*	*1.668*	*0.778*
N	0.823	0.804	-0.016	2.489	0.02
		0.949	*2.267*	*3.243*	*0.744*
NW	0.641	0.339	-0.009	2.088	0.037
		0.274	*1.081*	*2.669*	*1.086*
SE	0.553	1.709	-0.005	1.22	0.018
		2.167	*0.706*	*2.117*	*0.801*
SW	0.817	1.313	-0.012	1.268	-0.002
		2.036	*0.933*	*1.641*	*0.062*
WM	0.812	-0.437	-0.009	0.314	-0.049
		0.429	*0.9*	*0.316*	*1.33*
Y	0.792	0.514	-0.011	1.916	0.02
		0.764	*1.982*	*3.162*	*0.911*
ALL	0.618	0.71	-0.021	-1.119	0.106
		2.98	*9.338*	*1.723*	*3.964*

Equation 4

	r2	k	dat	dtq	dfe
EA	0.863	0.231	-0.06	0.011	-0.07
		0.198	*2.884*	*3.129*	*1.538*
EM	0.942	-0.529	-0.001	0.001	-0.049
		1.664	*0.283*	*0.439*	*3.384*
GL	0.378	3.129	-0.024	0.009	0.03
		1.676	*0.976*	*1.672*	*0.632*
N	0.843	0.654	-0.02	0.012	0.009
		0.817	*2.765*	*3.46*	*0.368*
NW	0.64	0.284	-0.011	0.009	0.029
		0.226	*1.337*	*2.609*	*0.832*
SE	0.584	1.822	-0.004	0.005	0.01
		2.107	*0.473*	*2.186*	*0.483*
SW	0.874	1.192	-0.017	0.007	0
		2.402	*1.649*	*2.342*	*0.011*
WM	0.811	-0.222	-0.015	0.003	-0.043
		0.216	*1.309*	*0.697*	*1.113*
Y	0.811	0.408	-0.014	0.009	0.012
		0.623	*2.432*	*3.32*	*0.656*
ALL	0.601	1.193	-0.02	0.008	0.01
		5.159	*8.867*	*7.377*	*1.136*

Equation 5

	r2	k	dat	f1/f2	dfe
EA	0.195	0.756	-0.03	0.406	-0.037
		0.324	*1.01*	*0.784*	*0.538*
EM	0.951	-0.786	-0.001	0.133	-0.046
		3.648	*0.691*	*1.166*	*6.4*
GL	0.122	2.404	-0.023	0.303	-0.005
		0.945	*0.776*	*0.478*	*0.074*
N	0.631	-1.426	-0.009	0.558	-0.029
		1.463	*0.969*	*1.282*	*0.796*
NW	0.448	-1.6	-0.006	0.588	0.003
		1.172	*0.59*	*1.424*	*0.08*
SE	0.307	0.856	-0.007	0.212	-0.01
		0.89	*0.707*	*0.687*	*0.363*
SW	0.817	0.109	-0.002	0.296	-0.038
		0.219	*0.287*	*1.37*	*1.686*
WM	0.841	-0.99	-0.013	0.347	-0.042
		1.661	*2.007*	*1.296*	*1.766*
Y	0.59	-1.208	-0.006	0.461	-0.015
		1.664	*0.86*	*1.366*	*0.644*
ALL	0.45	0.051	-0.016	0.488	-0.009
		0.166	*6.368*	*3.962*	*0.822*

Equation 6

	r2	k	dat	ln(f1/f2)	dfe
EA	0.713	0.131	-0.079	3.418	-0.071
		0.122	*3.466*	*3.644*	*1.697*
EM	0.945	-0.449	-0.002	0.293	-0.045
		1.376	*0.448*	*0.718*	*3.129*
GL	0.344	3.214	-0.03	2.102	0.039
		1.671	*1.163*	*1.628*	*0.619*
N	0.817	0.747	-0.015	2.385	0.018
		0.829	*2.176*	*3.063*	*0.68*
NW	0.629	0.296	-0.008	2.038	0.038
		0.231	*0.972*	*2.437*	*0.976*
SE	0.534	1.67	-0.006	1.151	0.016
		2.004	*0.789*	*1.904*	*0.611*
SW	0.82	1.154	-0.01	1.078	-0.012
		1.686	*0.862*	*1.416*	*0.324*
WM	0.805	-0.362	-0.012	0.49	-0.048
		0.347	*1.271*	*0.62*	*1.212*
Y	0.784	0.486	-0.01	1.845	0.019
		0.668	*1.888*	*2.99*	*0.761*
ALL	0.567	1.547	-0.019	1.832	0.022
		6.867	*8.176*	*6.68*	*1.962*

Ratio of Access Time

Equation 1

	r2	k	rwt	dfq	wdfe
EA	0.52	6.178	-3.486	0.006	-0.019
		3.392	*1.848*	*1.835*	*0.464*
EM	0.971	-0.752	0.128	-0.001	-0.052
		3.29	*1.618*	*0.73*	*8.237*
GL	0.38	6.833	-3.239	0.008	0.025
		2.131	*0.759*	*1.429*	*0.427*
N	0.859	4.352	-3.585	0.011	0.009
		2.407	*3.03*	*3.823*	*0.442*
NW	0.735	0.756	-0.529	0.006	0.012
		0.724	*2.14*	*2.326*	*0.578*
SE	0.588	2.097	-0.34	0.006	0.013
		1.852	*0.215*	*2.104*	*0.648*
SW	0.918	4.712	-3.161	0.008	0.008
		3.222	*2.764*	*3.671*	*0.459*
WM	0.861	1.026	-0.761	0.004	-0.032
		0.95	*2.16*	*1.281*	*1.316*
Y	0.837	1.477	-1.059	0.008	0.007
		1.675	*2.796*	*3.728*	*0.462*
ALL	0.483	2.254	-0.812	0.007	0.005
		6.492	*6.421*	*5.576*	*0.568*

Equation 2

	r2	k	rwt	f1/f2	wdfe
EA	0.452	6.171	-4.759	0.605	-0.04
		3.139	*1.976*	*1.481*	*0.969*
EM	0.97	-0.865	0.062	0.041	-0.046
		3.781	*1.07*	*0.636*	*8.499*
GL	0.185	7.307	-4.822	0.213	-0.015
		1.794	*0.964*	*0.341*	*0.23*
N	0.622	0.225	-1.497	0.528	-0.025
		0.102	*0.926*	*1.293*	*0.81*
NW	0.612	-0.102	-0.526	0.431	0.004
		0.071	*1.747*	*1.338*	*0.137*
SE	0.309	2.515	-1.549	0.165	-0.009
		1.299	*0.727*	*0.466*	*0.326*
SW	0.814	0.905	-0.662	0.346	-0.028
		0.681	*0.678*	*1.623*	*1.466*
WM	0.862	-0.156	-0.528	0.277	-0.042
		0.242	*2.402*	*1.311*	*2.621*
Y	0.598	-0.518	-0.504	0.416	-0.014
		0.463	*0.971*	*1.43*	*0.618*
ALL	0.367	1.203	-0.759	0.392	-0.008
		2.996	*4.983*	*3.116*	*0.82*

Equation 3

	r2	k	rwt	ln(f1/f2)	wdfe
EA	0.499	6.665	-3.729	1.394	-0.013
		3.404	*1.891*	*1.722*	*0.308*
EM	0.97	-0.741	0.113	-0.127	-0.052
		2.779	*1.432*	*0.507*	*6.415*
GL	0.354	7.752	-4.073	1.726	0.028
		2.441	*0.964*	*1.309*	*0.446*
N	0.838	3.735	-2.846	2.425	0.019
		2.02	*2.479*	*3.45*	*0.766*
NW	0.719	0.805	-0.462	1.469	0.021
		0.75	*1.782*	*2.185*	*0.856*
SE	0.54	2.667	-0.878	1.157	0.017
		2.422	*0.56*	*1.829*	*0.724*
SW	0.862	4.355	-2.834	1.595	0.011
		2.156	*1.763*	*2.367*	*0.394*
WM	0.875	1.011	-0.695	0.896	-0.029
		0.869	*2.064*	*1.142*	*1.003*
Y	0.82	1.409	-0.865	1.746	0.016
		1.524	*2.331*	*3.456*	*0.857*
ALL	0.463	2.479	-0.878	1.486	0.014
		6.685	*6.114*	*5.175*	*1.352*

Equation 4

	r2	k	rwt	dfq	dfe
EA	0.535	6.21	-3.643	0.006	-0.028
		3.826	*2.094*	*1.729*	*0.639*
EM	0.955	-0.946	0.133	-0.001	-0.061
		3.026	*1.323*	*0.786*	*6.393*
GL	0.369	7.23	3.778	0.007	0.018
		2.401	*0.922*	*1.293*	*0.274*
N	0.857	4.212	-3.483	0.011	0.008
		2.316	*3.002*	*3.67*	*0.323*
NW	0.731	0.732	-0.517	0.006	0.012
		0.687	*2.1*	*2.2*	*0.479*
SE	0.575	2.206	-0.49	0.005	0.011
		1.969	*0.311*	*1.93*	*0.48*
SW	0.915	4.381	-2.896	0.007	0.004
		2.996	*2.632*	*3.386*	*0.201*
WM	0.915	4.381	-2.896	0.007	0.004
		2.996	*2.632*	*3.386*	*0.201*
Y	0.835	1.438	-1.035	0.008	0.007
		1.693	*2.772*	*3.681*	*0.369*
ALL	0.482	2.236	-0.904	0.006	0.004
		6.204	*6.374*	*6.282*	*0.368*

Equation 5

	r2	k	rwt	f1/f2	dfe
EA	0.484	6.099	-4.806	0.571	-0.051
		3.677	*2.226*	*1.449*	*1.162*
EM	0.952	-0.79	0.048	0.047	-0.051
		3.644	*0.665*	*0.476*	*6.623*
GL	0.2	7.621	-5.065	0.137	-0.029
		2.048	*1.114*	*0.22*	*0.409*
N	0.633	0.183	-1.513	0.501	-0.032
		0.086	*0.974*	*1.249*	*0.919*
NW	0.61	-0.113	-0.516	0.403	0
		0.078	*1.73*	*1.226*	*0*
SE	0.325	2.61	-1.676	0.12	-0.015
		1.432	*0.819*	*0.344*	*0.603*
SW	0.827	0.858	-0.666	0.326	-0.034
		0.675	*0.647*	*1.689*	*1.66*
WM	0.878	-0.196	-0.571	0.292	-0.046
		0.296	*2.627*	*1.368*	*2.399*
Y	0.606	-0.549	-0.504	0.395	-0.019
		0.483	*1.002*	*1.367*	*0.719*
ALL	0.372	1.196	-0.753	0.359	-0.013
		2.976	*4.98*	*2.829*	*1.154*

Equation 6

	r2	k	rwt	ln(f1/f2)	dfe
EA	0.511	6.717	-3.912	1.315	-0.023
		3.778	*2.141*	*1.699*	*0.502*
EM	0.951	-0.863	0.101	-0.132	-0.059
		2.366	*0.995*	*0.394*	*4.804*
GL	0.341	8.12	-4.608	1.586	0.02
		2.688	*1.136*	*1.168*	*0.279*
N	0.833	3.542	-2.702	2.336	0.018
		1.893	*2.397*	*3.263*	*0.604*
NW	0.711	0.789	-0.446	1.442	0.022
		0.716	*1.704*	*2.023*	*0.729*
SE	0.522	2.779	-1.05	1.065	0.014
		2.61	*0.671*	*1.623*	*0.623*
SW	0.858	3.782	-2.216	1.396	0.003
		1.927	*1.698*	*2.107*	*0.079*
WM	0.858	3.782	-2.216	1.396	0.003
		1.927	*1.698*	*2.107*	*0.079*
Y	0.814	1.356	-0.827	1.899	0.016
		1.418	*2.26*	*3.261*	*0.718*
ALL	0.567	1.547	-0.019	1.832	0.022
		6.867	*8.176*	*6.68*	*1.962*

Appendix D Difference in Access Time

BUSINESS PAX FOREIGN CHARTER MODEL

Equation 1

	r2	k	dst	dfq	wdfa
EA	0.905	-0.307	-0.068	0.021	-0.101
		0.286	*3.084*	*6.924*	*2.488*
EM	0.704	-3.693	0.029	-0.002	-0.097
		2.001	*0.901*	*0.104*	*1.196*
GL	0.471	4.633	-0.025	0.012	0.096
		1.728	*0.689*	*1.679*	*1.414*
N	0.831	1.328	0.009	0.002	-0.046
		1.876	*1.344*	*0.682*	*2.184*
NW	0.805	0.246	-0.01	0.019	0.014
		0.124	*0.723*	*3.316*	*0.286*
SE	0.911	0.712	-0.01	0.005	0.003
		2.271	*2.969*	*4.942*	*0.406*
SW	0.769	2.675	-0.016	0.015	0.042
		2.762	*0.632*	*2.338*	*0.726*
WM	0.474	-1.307	-0.01	0.009	-0.05
		0.36	*0.218*	*0.493*	*0.383*
Y	0.909	0.231	0.003	0.013	-0.007
		0.283	*0.408*	*3.606*	*0.304*
ALL	0.434	1.409	-0.013	0.013	0.014
		3.361	*2.987*	*6.344*	*0.938*

Equation 2

	r2	k	dst	f1/f2	wdfa
EA	0.622	-0.911	-0.023	1.321	-0.037
		0.329	*0.569*	*2.08*	*0.498*
EM	0.737	4.284	0.015	0.666	-0.054
		3.024	*0.926*	*0.883*	*1.081*
GL	0.274	3.856	-0.022	0.409	0.061
		1.117	*0.535*	*0.479*	*0.738*
N	0.822	1.11	0.014	-0.11	-0.064
		1.833	*2.353*	*0.404*	*3.224*
NW	0.644	-3.677	0.001	1.322	-0.028
		1.546	*0.075*	*1.821*	*0.428*
SE	0.683	-0.049	-0.012	0.3	-0.007
		0.064	*1.938*	*1.604*	*0.463*
SW	0.668	0.463	0.02	0.654	-0.034
		0.433	*1.104*	*1.406*	*0.772*
WM	0.561	-3.591	-0.009	1.212	-0.033
		1.674	*0.373*	*1.216*	*0.415*
Y	0.796	-2.006	0.014	0.714	-0.036
		1.955	*1.351*	*1.579*	*1.089*
ALL	0.332	-0.626	-0.008	0.984	0
		1.125	*1.744*	*4.571*	*0.027*

Equation 3

	r2	k	dst	ln(f1/f2)	wdfa
EA	0.874	-0.232	-0.093	5.953	-0.097
		0.186	*3.133*	*4.997*	*2.076*
EM	0.704	-3.298	0.022	0.449	-0.076
		1.679	*0.917*	*0.164*	*0.908*
GL	0.448	4.742	-0.031	2.71	0.107
		1.73	*0.861*	*1.483*	*1.431*
N	0.826	1.299	0.011	0.373	-0.046
		1.744	*1.696*	*0.662*	*1.932*
NW	0.8	0.284	-0.003	4.304	0.032
		0.141	*0.262*	*3.266*	*0.677*
SE	0.889	0.777	-0.012	1.118	0.009
		2.188	*3.348*	*4.308*	*0.963*
SW	0.667	2.886	0.001	2.442	0.02
		1.969	*0.032*	*1.396*	*0.261*
WM	0.461	-1.825	0	1.164	-0.07
		0.487	*0.009*	*0.319*	*0.619*
Y	0.9	0.366	0.008	2.649	0.004
		0.414	*1.091*	*3.373*	*0.14*
ALL	0.398	1.928	-0.011	2.927	0.031
		4.18	*2.67*	*6.716*	*1.704*

Equation 4

	r2	k	dst	dfq	dfa
EA	0.897	-0.223	-0.059	0.02	-0.101
		0.198	*2.906*	*6.627*	*2.289*
EM	0.674	-3.438	0.019	0.003	-0.082
		1.664	*0.601*	*0.194*	*0.876*
GL	0.438	4.58	-0.03	0.012	0.1
		1.606	*0.839*	*1.604*	*1.24*
N	0.848	1.164	0.009	0.002	-0.055
		1.663	*1.417*	*0.699*	*2.419*
NW	0.804	0.164	-0.009	0.019	0.012
		0.081	*0.691*	*3.217*	*0.216*
SE	0.909	0.693	-0.01	0.005	0.002
		2.129	*3.049*	*4.682*	*0.249*
SW	0.756	2.529	-0.008	0.013	0.027
		2.32	*0.366*	*2.079*	*0.432*
WM	0.469	-1.079	-0.015	0.011	-0.043
		0.288	*0.361*	*0.624*	*0.309*
Y	0.909	0.172	0.003	0.012	-0.01
		0.204	*0.462*	*3.642*	*0.379*
ALL	0.433	1.432	-0.013	0.013	0.014
		3.236	*2.946*	*6.101*	*0.807*

Equation 5

	r2	k	dst	f1/f2	dfa
EA	0.642	-1.414	-0.029	1.328	-0.061
		0.622	*0.821*	*2.206*	*0.766*
EM	0.723	-4.51	0.012	0.788	-0.051
		3.203	*0.776*	*1.049*	*0.909*
GL	0.245	3.715	-0.028	0.332	0.051
		1.047	*0.681*	*0.376*	*0.642*
N	0.842	0.963	0.013	-0.115	-0.074
		1.689	*2.401*	*0.464*	*3.632*
NW	0.649	-3.757	0.002	1.274	-0.037
		1.682	*0.091*	*1.773*	*0.623*
SE	0.692	-0.07	-0.012	0.278	-0.011
		0.12	*2.032*	*1.496*	*0.629*
SW	0.68	0.378	0.02	0.614	-0.043
		0.364	*1.211*	*1.363*	*0.917*
WM	0.558	-3.655	-0.011	1.257	-0.032
		1.696	*0.46*	*1.296*	*0.376*
Y	0.802	-2.09	0.013	0.693	-0.044
		2.07	*1.387*	*1.68*	*1.196*
ALL	0.332	-0.606	-0.008	0.942	-0.006
		1.107	*1.7*	*4.327*	*0.3*

Equation 6

	r2	k	dst	ln(f1/f2)	dfa
EA	0.867	-0.156	-0.083	5.518	-0.097
		0.122	*3.074*	*4.822*	*1.949*
EM	0.684	-2.954	0.015	1.238	-0.058
		1.376	*0.663*	*0.463*	*0.616*
GL	0.41	4.665	-0.037	2.675	0.11
		1.697	*0.999*	*1.363*	*1.233*
N	0.842	1.125	0.01	0.295	-0.056
		1.616	*1.791*	*0.46*	*2.176*
NW	0.798	0.205	-0.002	4.228	0.031
		0.099	*0.17*	*3.137*	*0.494*
SE	0.884	0.761	-0.012	1.087	0.009
		2.018	*3.411*	*3.97*	*0.747*
SW	0.663	2.376	0.008	1.989	-0.001
		1.61	*0.314*	*1.211*	*-0.016*
WM	0.454	-1.557	-0.005	1.578	-0.062
		0.411	*0.139*	*0.46*	*0.429*
Y	0.9	0.307	0.008	2.581	0.001
		0.331	*1.198*	*3.282*	*0.038*
ALL	0.393	1.971	-0.011	2.854	0.032
		3.936	*2.468*	*6.396*	*1.468*

Ratio of Access Time

Equation 1

	r2	k	rat	dfq	wdfe
EA	0.798	4.81	-2.462	0.014	-0.032
		2.337	*1.154*	*3.906*	*0.897*
EM	0.776	4.886	1.049	0	-0.09
		2.799	*1.742*	*0.026*	*1.881*
GL	0.465	8.784	-3.776	0.01	0.086
		1.96	*0.633*	*1.303*	*1.072*
N	0.829	-0.186	1.522	0.003	-0.044
		0.105	*1.311*	*0.855*	*2.157*
NW	0.839	1.091	-0.579	0.016	0.004
		0.614	*1.376*	*3.639*	*0.104*
SE	0.891	2.598	-1.818	0.004	0.002
		4.925	*2.464*	*3.505*	*0.18*
SW	0.814	8.986	-3.766	0.017	0.061
		2.014	*1.368*	*3.385*	*1.398*
WM	0.822	4.027	-2.119	0.023	0.041
		0.963	*1.553*	*1.729*	*0.446*
Y	0.906	0.441	0.022	0.013	-0.002
		0.352	*0.042*	*4.456*	*0.07*
ALL	0.456	2.534	0.833	0.013	0.014
		4.436	*3.536*	*6.545*	*0.987*

Equation 2

	r2	k	rat	f1/f2	wdfe
EA	0.811	5.131	-6.381	1.706	-0.087
		2.553	*2.591*	*4.089*	*2.016*
EM	0.815	-5.273	0.77	0.587	-0.058
		4.404	*1.942*	*1.128*	*1.577*
GL	0.321	9.557	-5.649	0.218	0.032
		1.709	*0.849*	*0.255*	*0.353*
N	0.808	-1.234	2.214	0.001	-0.058
		0.885	*2.161*	*0.003*	*2.977*
NW	0.69	-1.435	-0.565	1.256	-0.014
		0.509	*0.946*	*2.002*	*0.272*
SE	0.698	2.771	-2.624	0.166	-0.013
		2.391	*2.058*	*0.781*	*0.798*
SW	0.626	-1.299	1.63	0.784	-0.017
		0.437	*0.636*	*1.642*	*0.396*
WM	0.617	-2.14	-0.877	1.403	-0.016
		0.847	*1.019*	*1.696*	*0.252*
Y	0.782	-3.008	0.828	0.909	-0.026
		1.912	*1.161*	*2.271*	*0.831*
ALL	0.351	0.248	-0.587	0.957	0
		0.38	*2.37*	*4.686*	*0.011*

Equation 3

	r2	k	rat	ln(f1/f2)	wdfe
EA	0.729	5.865	-2.967	3.25	-0.019
		2.345	*1.174*	*3.132*	*0.363*
EM	0.776	4.835	1.03	0.023	-0.069
		2.427	*1.745*	*0.012*	*1.474*
GL	0.444	9.956	-4.847	2.187	0.09
		2.249	*0.822*	*1.169*	*1.035*
N	0.823	-0.439	1.753	0.463	-0.044
		0.255	*1.642*	*0.709*	*1.867*
NW	0.821	1.221	-0.398	3.943	0.029
		0.654	*0.882*	*3.372*	*0.669*
SE	0.868	3.028	-2.205	0.926	0.006
		5.863	*2.896*	*3.014*	*0.519*
SW	0.691	5.939	-2.42	3.363	0.063
		1.248	*0.687*	*2.13*	*0.929*
WM	0.567	3.524	-1.651	4.334	0.044
		0.748	*1.211*	*1.364*	*0.38*
Y	0.868	0.308	0.358	2.948	0.013
		0.227	*0.656*	*3.966*	*0.471*
ALL	0.42	2.946	-0.76	2.826	0.031
		4.765	*3.174*	*5.903*	*1.756*

Equation 4

	r2	k	rat	dfq	dfe
EA	0.802	4.86	-2.464	0.014	-0.039
		2.638	*1.247*	*3.768*	*0.786*
EM	0.759	-5.106	1.024	0	-0.101
		2.686	*1.606*	*0.02*	*1.684*
GL	0.437	9.719	-4.822	0.01	0.083
		2.272	*0.828*	*1.173*	*0.893*
N	0.845	-0.327	1.496	0.002	-0.054
		0.194	*1.391*	*0.766*	*2.399*
NW	0.839	1.032	-0.569	0.016	0.001
		0.673	*1.368*	*3.466*	*0.019*
SE	0.89	2.624	-1.874	0.004	0
		6.091	*2.68*	*3.316*	*0.02*
SW	0.791	8.028	-2.897	0.016	0.054
		1.662	*1.062*	*2.938*	*1.039*
WM	0.621	4.04	-2.074	0.023	0.046
		0.968	*1.611*	*1.748*	*0.444*
Y	0.906	0.372	0.044	0.013	-0.004
		0.292	*0.083*	*4.319*	*0.166*
ALL	0.454	2.546	-0.823	0.013	0.015
		4.289	*3.624*	*6.286*	*0.866*

Equation 5

	r2	k	rat	f1/f2	dfe
EA	0.821	4.628	-6.006	1.631	-0.097
		2.642	*2.707*	*4.031*	*2.14*
EM	0.803	-5.428	0.737	0.632	-0.061
		4.399	*1.812*	*1.164*	*1.397*
GL	0.31	10.365	-6.585	0.117	0.017
		1.998	*1.037*	*0.134*	*0.17*
N	0.83	-1.229	2.061	-0.017	-0.069
		0.942	*2.217*	*0.07*	*3.289*
NW	0.695	-1.469	-0.548	1.193	-0.024
		0.624	*0.962*	*1.878*	*0.412*
SE	0.712	2.77	-2.658	0.142	-0.017
		2.669	*2.197*	*0.689*	*0.979*
SW	0.635	-1.514	1.798	0.727	-0.027
		0.621	*0.741*	*1.648*	*0.662*
WM	0.617	-2.156	-0.893	1.406	-0.018
		0.849	*1.076*	*1.716*	*0.248*
Y	0.789	-3.057	0.82	0.878	-0.033
		1.966	*1.189*	*2.218*	*0.943*
ALL	0.351	0.253	-0.575	0.916	-0.005
		0.389	*2.333*	*4.422*	*0.268*

Equation 6

	r2	k	rat	ln(f1/f2)	dfe
EA	0.733	5.859	-3.075	3.171	-0.029
		2.66	*1.307*	*2.996*	*0.484*
EM	0.759	-4.901	0.966	0.193	-0.094
		2.164	*1.666*	*0.096*	*1.268*
GL	0.414	10.866	-5.901	2.03	0.065
		2.637	*1.026*	*1.044*	*0.841*
N	0.84	-0.576	1.71	0.374	-0.054
		0.364	*1.744*	*0.699*	*2.118*
NW	0.818	1.186	-0.376	3.869	0.028
		0.619	*0.828*	*3.16*	*0.664*
SE	0.864	3.068	-2.28	0.88	0.004
		6.743	*3.02*	*2.78*	*0.326*
SW	0.664	4.352	-1.17	2.844	0.043
		0.914	*0.348*	*1.769*	*0.661*
WM	0.566	3.407	-1.573	4.21	0.045
		0.727	*1.263*	*1.376*	*0.363*
Y	0.866	0.22	0.401	2.876	0.011
		0.167	*0.748*	*3.783*	*0.346*
ALL	0.415	2.966	-0.738	2.763	0.032
		4.641	*-3.084*	*6.666*	*1.609*

Difference in Access Time

LEISURE IT PAX FOREIGN CHARTER MODEL

Equation 1

	r2	k	dat	dfq	wdfa
EA	0.628	0.434	-0.097	0.013	-0.145
		0.286	*3.127*	*2.667*	*2.62*
EM	0.862	2.774	-0.069	0.038	0.078
		2.001	*2.848*	*3.386*	*1.288*
GL	0.41	5.542	-0.026	0.013	0.103
		1.721	*0.698*	*1.462*	*1.266*
N	1.000	0.106	0.031	0.003	-0.051
		2.118	*63.463*	*12.069*	*34.276*
NW	0.772	0.332	-0.015	0.019	0.023
		0.158	*0.968*	*3.092*	*0.423*
SE	0.642	0.438	-0.042	-0.005	-0.029
		0.343	*3.234*	*1.127*	*0.902*
SW	0.698	3.907	0.002	0.017	0.109
		2.762	*0.048*	*1.817*	*1.299*
WM	0.502	0.152	0.01	-0.012	-0.15
		0.049	*0.269*	*0.762*	*1.374*
Y	0.337	-0.4033	-0.009	-0.001	-0.058
		1.939	*0.466*	*0.169*	*0.964*
ALL	0.26	2.431	-0.023	0.011	0.024
		4.6	*4.247*	*4.16*	*1.238*

Equation 2

	r2	k	dat	f1/f2	wdfa
EA	0.26	1.643	-0.052	0.353	-0.09
		0.594	*1.35*	*0.557*	*1.193*
EM	0.601	-0.935	0.005	0.166	-0.104
		0.486	*0.221*	*0.162*	*1.56*
GL	0.223	4.785	-0.023	0.392	0.061
		1.178	*0.472*	*0.391*	*0.63*
N	0.993	-0.347	0.034	0.124	-0.059
		1.954	*18.885*	*1.552*	*10.05*
NW	0.605	-3.554	-0.003	1.302	-0.02
		1.443	*0.163*	*1.731*	*0.294*
SE	0.645	1.318	-0.042	-0.466	-0.03
		1.043	*3.257*	*1.157*	*0.937*
SW	0.618	1.398	0.042	0.742	0.023
		0.953	*1.697*	*1.163*	*0.391*
WM	0.455	2.044	-0.016	-0.036	-0.076
		1.002	*0.645*	*0.038*	*1.025*
Y	0.626	-4.202	-0.019	0.569	-0.017
		2.508	*1.153*	*0.757*	*0.314*
ALL	0.18	0.89	-0.018	0.716	0.006
		1.281	*3.316*	*2.064*	*0.273*

Equation 3

	r2	k	dat	ln(f1/f2)	wdfa
EA	0.677	0.265	-0.12	3.958	-0.148
		0.186	*3.609*	*2.907*	*2.772*
EM	0.819	2.838	-0.042	6.36	0.07
		1.679	*2.026*	*2.706*	*0.966*
GL	0.368	5.661	-0.033	2.945	0.114
		1.723	*0.747*	*1.346*	*1.273*
N	0.999	0.136	0.032	0.56	-0.049
		1.928	*64.287*	*8.723*	*21.366*
NW	0.766	0.367	-0.008	4.265	0.04
		0.172	*0.646*	*3.036*	*0.678*
SE	0.639	0.371	-0.04	-0.1051	-0.035
		0.286	*3.192*	*1.103*	*0.966*
SW	0.601	3.756	0.024	2.492	0.073
		1.969	*0.616*	*1.019*	*0.667*
WM	0.525	-0.234	0.008	-2.749	-0.169
		0.078	*0.263*	*0.938*	*1.663*
Y	0.334	-3.861	-0.011	-0.081	-0.052
		1.796	*0.619*	*0.042*	*0.768*
ALL	0.233	2.843	-0.022	2.398	0.036
		4.846	*3.939*	*3.681*	*1.668*

Equation 4

	r2	k	dat	dfq	dfa
EA	0.659	0.289	-0.089	0.011	-0.157
		0.198	*3.393*	*2.428*	*2.739*
EM	0.847	2.592	-0.061	0.034	0.068
		1.664	*2.677*	*3.061*	*0.969*
GL	0.379	5.435	-0.032	0.013	0.105
		1.6	*0.741*	*1.366*	*1.093*
N	1	-0.009	0.03	0.003	-0.058
		1.903	*689.666*	*127.906*	*371.363*
NW	0.77	0.248	-0.013	0.019	0.021
		0.116	*0.933*	*2.991*	*0.349*
SE	0.639	0.386	-0.042	-0.005	-0.032
		0.293	*3.228*	*1.11*	*0.877*
SW	0.664	3.79	0.015	0.014	0.091
		2.32	*0.432*	*1.489*	*0.961*
WM	0.486	0.334	0.001	-0.009	-0.15
		0.106	*0.031*	*0.621*	*1.281*
Y	0.31	-3.955	-0.012	-0.001	-0.057
		1.788	*0.691*	*0.069*	*0.799*
ALL	0.256	2.465	-0.023	0.011	0.024
		4.319	*4.184*	*3.94*	*1.063*

Equation 5

	r2	k	dat	f1/f2	dfa
EA	0.36	1.018	-0.058	0.33	-0.123
		0.393	*1.722*	*0.673*	*1.606*
EM	0.613	-1.258	0.003	0.177	-0.119
		0.686	*0.142*	*0.181*	*1.642*
GL	0.197	4.61	-0.03	0.301	0.049
		1.107	*0.612*	*0.289*	*0.439*
N	0.995	-0.481	0.033	0.136	-0.066
		3.03	*21.147*	*1.933*	*11.317*
NW	0.609	-3.631	-0.003	1.251	-0.029
		1.473	*0.147*	*1.678*	*0.389*
SE	0.64	1.27	-0.041	-0.454	-0.033
		0.996	*3.227*	*1.112*	*0.88*
SW	0.612	1.474	0.045	0.666	0.016
		1.01	*1.923*	*1.06*	*0.246*
WM	0.453	1.864	-0.018	0.009	-0.083
		0.92	*0.796*	*0.009*	*1.01*
Y	0.386	-4.231	-0.02	0.631	-0.012
		2.613	*1.268*	*0.863*	*0.194*
ALL	0.179	0.935	-0.018	0.662	0
		1.366	*3.268*	*2.436*	*0.009*

Equation 6

	r2	k	dat	ln(f1/f2)	dfa
EA	0.7	0.167	-0.107	3.364	-0.159
		0.122	*3.717*	*2.736*	*2.962*
EM	0.806	2.549	-0.036	5.672	0.054
		1.376	*1.821*	*2.465*	*0.668*
GL	0.35	5.546	-0.039	2.865	0.116
		1.691	*0.888*	*1.231*	*1.087*
N	1	0.029	0.031	0.566	-0.056
		1.694	*236.992*	*37.23*	*92.092*
NW	0.762	0.284	-0.006	4.183	0.04
		0.129	*0.464*	*2.914*	*0.69*
SE	0.636	0.312	-0.04	-1.058	-0.039
		0.23	*3.166*	*1.076*	*0.921*
SW	0.581	3.383	0.036	1.782	0.044
		1.61	*1.028*	*0.762*	*0.379*
WM	0.504	-0.036	-0.001	-2.198	-0.168
		0.012	*0.027*	*0.788*	*1.436*
Y	0.31	-3.736	-0.013	0.177	-0.047
		1.626	*0.768*	*0.091*	*0.691*
ALL	0.226	2.871	-0.021	2.281	0.035
		4.606	*3.831*	*3.39*	*1.276*

Ratio of Access Time

Equation 1

	r2	k	rnt	dfq	wdfe
EA	0.411	9.265	-5.197	0.003	-0.074
		3.684	*1.994*	*0.72*	*1.329*
EM	0.766	2.141	-1.034	0.019	-0.016
		1.09	*1.525*	*2.148*	*0.288*
GL	0.404	9.831	-3.861	0.011	0.093
		1.827	*0.542*	*1.197*	*0.962*
N	0.983	-4.836	5.007	0.004	-0.045
		5.701	*9.019*	*2.923*	*4.546*
NW	0.819	1.182	-0.724	0.015	0.005
		0.638	*1.651*	*3.225*	*0.137*
SE	0.497	8.576	-7.698	-0.007	-0.033
		3.726	*2.391*	*1.303*	*0.845*
SW	0.717	7.407	-2.746	0.021	0.151
		1.358	*0.644*	*2.89*	*2.197*
WM	0.596	5.038	-1.465	0.004	-0.045
		1.366	*1.218*	*0.333*	*0.546*
Y	0.343	-3.31	-0.686	-0.002	-0.06
		1.056	*0.511*	*0.28*	*1.063*
ALL	0.28	4.242	-1.365	0.01	0.022
		5.73	*4.571*	*3.898*	*1.175*

Equation 2

	r2	k	rnt	f1/f2	wdfe
EA	0.417	9.36	-6.137	0.401	-0.086
		3.705	*1.982*	*0.764*	*1.591*
EM	0.598	-1.039	-0.004	0.339	-0.095
		0.533	*0.006*	*0.4*	*1.594*
GL	0.266	10.949	-6.054	0.186	0.029
		1.641	*0.77*	*0.186*	*0.274*
N	0.986	-6.106	5.409	0.36	-0.047
		10.553	*12.715*	*3.349*	*5.77*
NW	0.861	-1.106	-0.705	1.141	-0.012
		0.394	*1.205*	*1.822*	*0.239*
SE	0.549	10.628	-8.42	-0.848	-0.044
		3.692	*2.657*	*1.607*	*1.118*
SW	0.53	-2.981	4.057	0.957	0.052
		0.7	*1.108*	*1.401*	*0.84*
WM	0.592	4.008	-1.216	0.166	-0.059
		1.802	*1.604*	*0.228*	*1.024*
Y	0.504	-2.898	-1.099	0.276	0.032
		1.129	*0.945*	*0.422*	*0.628*
ALL	0.206	2.838	-1.164	0.613	0.004
		3.245	*3.774*	*2.411*	*0.216*

Equation 3

	r2	k	rnt	ln(f1/f2)	wdfe
EA	0.398	9.461	-5.274	0.683	-0.072
		3.539	*1.959*	*0.618*	*1.252*
EM	0.806	3.342	-1.119	5.021	0.032
		1.636	*1.648*	*2.606*	*0.514*
GL	0.364	11.125	-5.069	2.397	0.097
		2.097	*0.716*	*1.068*	*0.926*
N	0.981	-5.094	5.294	0.849	-0.042
		5.869	*9.825*	*2.573*	*3.486*
NW	0.802	1.302	-0.558	3.638	0.028
		0.673	*1.194*	*3.005*	*0.631*
SE	0.505	7.935	-7.21	-1.633	-0.044
		3.776	*2.409*	*1.352*	*0.987*
SW	0.576	5.526	-0.65	3.999	0.144
		0.776	*0.123*	*1.683*	*1.419*
WM	0.589	4.092	-1.139	0.033	-0.068
		1.043	*1.003*	*0.012*	*0.704*
Y	0.337	-3.101	-0.808	-0.281	-0.057
		0.99	*0.643*	*0.164*	*0.891*
ALL	0.255	4.52	-1.317	2.105	0.033
		5.729	*4.312*	*3.445*	*1.45*

Equation 4

	r2	k	rnt	dfq	dfe
EA	0.46	8.992	-5.243	0.002	-0.092
		4.123	*2.243*	*0.666*	*1.669*
EM	0.766	2.093	-1.036	0.019	-0.018
		0.977	*1.498*	*2.037*	*0.274*
GL	0.377	10.876	-5.076	0.01	0.066
		2.124	*0.726*	*1.072*	*0.788*
N	0.985	-4.873	4.92	0.004	-0.052
		6.119	*9.69*	*2.968*	*4.918*
NW	0.818	1.12	-0.713	0.015	0.002
		0.597	*1.644*	*3.064*	*0.06*
SE	0.497	8.387	-7.591	-0.007	-0.039
		3.739	*2.402*	*1.3*	*0.846*
SW	0.656	5.773	-1.132	0.019	0.145
		0.976	*0.264*	*2.191*	*1.716*
WM	0.599	4.669	-1.475	0.004	-0.054
		1.32	*1.304*	*0.313*	*0.69*
Y	0.313	-3.145	-0.833	-0.002	-0.061
		0.965	*0.618*	*0.191*	*0.931*
ALL	0.276	4.252	-1.368	0.01	0.022
		6.524	*4.616*	*3.693*	*0.994*

Equation 5

	r2	k	rnt	f1/f2	dfe
EA	0.47	9.026	-5.992	0.328	-0.102
		4.192	*2.197*	*0.669*	*1.84*
EM	0.612	-1.3	-0.005	0.281	-0.114
		0.681	*0.007*	*0.336*	*1.688*
GL	0.258	11.762	-7.105	0.068	0.011
		1.919	*0.948*	*0.066*	*0.093*
N	0.989	-6.085	5.286	0.353	-0.054
		12.196	*14.728*	*3.815*	*6.81*
NW	0.865	-1.141	-0.698	1.079	-0.022
		0.408	*1.212*	*1.7*	*0.377*
SE	0.541	10.266	-8.143	-0.922	-0.047
		3.711	*2.622*	*1.566*	*1.069*
SW	0.509	-3.445	4.641	0.861	0.045
		0.601	*1.293*	*1.238*	*0.66*
WM	0.596	3.928	-1.259	0.158	-0.068
		1.764	*1.728*	*0.219*	*1.066*
Y	0.338	-2.866	-1.186	0.336	-0.029
		1.101	*1.027*	*0.607*	*0.493*
ALL	0.206	2.654	-1.148	0.563	-0.001
		3.276	*3.736*	*2.182*	*0.061*

Equation 6

	r2	k	rnt	ln(f1/f2)	dfe
EA	0.45	9.133	-5.305	0.483	-0.092
		3.886	*2.196*	*0.444*	*1.608*
EM	0.805	3.413	-1.107	5.006	0.035
		1.616	*1.812*	*2.487*	*0.479*
GL	0.354	12.128	-6.264	2.2	0.069
		2.37	*0.911*	*0.947*	*0.739*
N	0.983	-5.127	5.205	0.814	-0.049
		6.333	*10.671*	*2.619*	*3.827*
NW	0.798	1.262	-0.536	3.578	0.027
		0.637	*1.142*	*2.801*	*0.616*
SE	0.504	7.666	-7.04	-1.65	-0.051
		3.696	*2.402*	*1.342*	*0.979*
SW	0.514	2.931	1.514	3.133	0.118
		0.401	*0.293*	*1.268*	*0.993*
WM	0.593	3.977	-1.187	0.013	-0.079
		1.026	*1.144*	*0.006*	*0.76*
Y	0.31	-2.871	-0.954	-0.063	-0.054
		0.882	*0.763*	*0.047*	*0.723*
ALL	0.249	4.509	-1.29	2.004	0.032
		6.413	*4.222*	*3.164*	*1.178*

<u>**Difference In Access Time**</u>

LEISURE OTHER PAX FOREIGN CHARTER MODEL

Equation 1

	r2	k	dst	dfq	wdfe
EA	0.864	0.495	-0.118	0.017	-0.153
		0.286	*3.322*	*2.919*	*2.336*
EM	0.851	0.758	-0.007	0.007	0.013
		2.001	*1.067*	*2.442*	*0.766*
GL	0.332	5.371	-0.025	0.012	0.073
		1.707	*0.604*	*1.436*	*0.916*
N	0.865	2.27	-0.014	0.014	-0.029
		2.132	*1.336*	*3.031*	*0.904*
NW	0.472	3.628	-0.029	0.019	0.081
		1.076	*1.202*	*1.976*	*0.941*
SE	0.599	2.1	-0.001	0.008	0.033
		2.276	*0.08*	*2.742*	*1.443*
SW	0.546	1.8	-0.001	0.006	0.018
		2.817	*0.089*	*1.346*	*0.466*
WM	0.897	-0.168	-0.005	0.002	-0.035
		0.312	*0.789*	*0.762*	*1.83*
Y	0.959	-0.572	-0.014	0.01	-0.085
		0.768	*1.994*	*3.146*	*3.904*
ALL	0.381	2.354	-0.022	0.011	0.021
		6.726	*6.167*	*5.672*	*1.406*

Equation 2

	r2	k	dst	f1/f2	wdfe
EA	0.289	1.892	-0.061	0.51	-0.083
		0.563	*1.302*	*0.864*	*0.911*
EM	0.703	0.07	0.008	-0.007	-0.025
		0.161	*1.593*	*0.029*	*1.678*
GL	0.124	4.849	-0.023	0.373	0.032
		1.174	*0.479*	*0.381*	*0.343*
N	0.733	0.004	0.003	0.44	-0.082
		0.003	*0.244*	*0.721*	*1.846*
NW	0.199	-0.057	-0.012	0.823	0.003
		0.015	*0.439*	*0.729*	*0.035*
SE	0.225	0.936	-0.005	0.405	0.012
		0.734	*0.4*	*0.995*	*0.357*
SW	0.459	1.011	0.013	0.208	-0.014
		1.579	*1.184*	*0.748*	*0.529*
WM	0.914	-0.629	-0.004	0.197	-0.036
		2.028	*1.085*	*1.368*	*3.143*
Y	0.932	-2.429	-0.007	0.677	-0.102
		3.021	*0.915*	*1.913*	*3.907*
ALL	0.226	0.988	-0.016	0.597	-0.005
		1.759	*3.481*	*2.745*	*0.326*

Equation 3

	r2	k	dst	ln(f1/f2)	wdfe
EA	0.732	0.3	-0.146	5.119	-0.157
		0.186	*3.799*	*3.328*	*2.698*
EM	0.819	0.747	-0.002	1.212	0.01
		1.679	*0.301*	*1.96*	*0.616*
GL	0.307	5.485	-0.032	2.846	0.084
		1.71	*0.76*	*1.332*	*0.962*
N	0.864	2.335	-0.008	2.85	-0.02
		1.941	*0.767*	*2.613*	*0.62*
NW	0.457	3.616	-0.022	4.304	0.086
		1.063	*0.963*	*1.906*	*1.016*
SE	0.547	2.184	-0.004	1.781	0.042
		2.187	*0.436*	*2.441*	*1.606*
SW	0.451	1.685	0.008	0.719	0.001
		2.042	*0.446*	*0.683*	*0.02*
WM	0.893	-0.248	-0.003	0.305	-0.038
		0.463	*0.607*	*0.672*	*1.91*
Y	0.959	-0.428	-0.011	2.181	-0.074
		0.656	*1.689*	*3.161*	*3.046*
ALL	0.356	2.813	-0.02	2.558	0.037
		6.288	*4.836*	*5.146*	*2.048*

Equation 4

	r2	k	dst	dfq	dfe
EA	0.709	0.331	-0.109	0.015	-0.166
		0.198	*3.641*	*2.867*	*2.638*
EM	0.843	0.692	-0.005	0.007	0.009
		1.664	*0.846*	*2.193*	*0.475*
GL	0.307	5.225	-0.03	0.012	0.072
		1.686	*0.732*	*1.342*	*0.769*
N	0.893	2.062	-0.013	0.013	-0.039
		1.916	*1.364*	*2.967*	*1.128*
NW	0.45	3.37	-0.025	0.018	0.077
		0.96	*1.078*	*1.817*	*0.781*
SE	0.57	2.097	-0.002	0.008	0.034
		2.131	*0.189*	*2.616*	*1.239*
SW	0.532	1.895	0.003	0.005	0.008
		2.393	*0.184*	*1.118*	*0.2*
WM	0.892	-0.135	-0.007	0.003	-0.035
		0.244	*1.19*	*1.012*	*1.714*
Y	0.957	-0.745	-0.016	0.01	-0.097
		0.943	*2.238*	*3.079*	*3.813*
ALL	0.376	2.37	-0.021	0.011	0.02
		6.446	*6.068*	*6.248*	*1.126*

Equation 5

	r2	k	dst	f1/f2	dfe
EA	0.367	1.115	-0.069	0.503	-0.122
		0.36	*1.676*	*0.708*	*1.296*
EM	0.716	-0.007	0.008	-0.007	-0.03
		0.017	*1.613*	*0.032*	*1.796*
GL	0.11	4.452	-0.028	0.277	0.017
		1.106	*0.606*	*0.276*	*0.162*
N	0.756	-0.188	0.002	0.4	-0.099
		0.146	*0.196*	*0.696*	*2.068*
NW	0.2	-0.186	-0.01	0.709	-0.011
		0.06	*0.386*	*0.631*	*0.101*
SE	0.212	0.936	-0.006	0.353	0.007
		0.726	*0.481*	*0.866*	*0.181*
SW	0.474	0.978	0.013	0.181	-0.019
		1.668	*1.322*	*0.668*	*0.677*
WM	0.909	-0.704	-0.005	0.22	-0.038
		2.206	*1.463*	*1.63*	*3.011*
Y	0.934	-2.654	-0.009	0.694	-0.115
		3.366	*1.232*	*2.027*	*4.011*
ALL	0.23	1.004	-0.015	0.533	-0.014
		1.821	*3.436*	*2.432*	*0.722*

Equation 6

	r2	k	dst	ln(f1/f2)	dfe
EA	0.749	0.189	-0.134	4.492	-0.169
		0.122	*4.078*	*3.226*	*2.766*
EM	0.813	0.656	0	1.048	0.005
		1.376	*0.069*	*1.768*	*0.243*
GL	0.276	5.331	-0.038	2.752	0.082
		1.678	*0.876*	*1.212*	*0.794*
N	0.87	2.101	-0.007	2.652	-0.032
		1.706	*0.736*	*2.493*	*0.749*
NW	0.43	3.333	-0.018	4.042	0.092
		0.928	*0.806*	*1.726*	*0.838*
SE	0.506	2.173	-0.005	1.703	0.043
		2.014	*0.661*	*2.176*	*1.26*
SW	0.457	1.493	0.011	0.479	-0.012
		1.7	*0.74*	*0.49*	*0.242*
WM	0.887	-0.21	-0.005	0.421	-0.038
		0.372	*1.027*	*0.826*	*1.768*
Y	0.958	-0.577	-0.012	2.168	-0.085
		0.713	*1.968*	*3.168*	*3.024*
ALL	0.345	2.83	-0.02	2.424	0.035
		6.802	*4.663*	*4.706*	*1.634*

Ratio of Access Time

Equation 1

	r2	k	rat	dfq	wdfa
EA	0.47	11.147	-6.241	0.005	-0.066
		3.77	*2.037*	*0.966*	*1.011*
EM	0.982	0.963	-0.222	0.007	0.009
		2.622	*1.749*	*4.039*	*0.896*
QL	0.324	9.543	-3.745	0.011	0.064
		1.813	*0.535*	*1.161*	*0.68*
N	0.869	4.791	2.45	0.014	0.029
		1.84	*1.437*	*3.214*	*0.968*
NW	0.504	3.971	1.062	0.012	0.037
		1.231	*1.369*	*1.486*	*0.571*
SE	0.599	2.106	0.077	0.008	0.034
		1.499	*0.039*	*2.504*	*1.428*
SW	0.583	3.52	-1.399	0.007	0.034
		1.446	*0.735*	*2.09*	*1.106*
WM	0.932	0.541	-0.379	0.003	-0.027
		0.935	*2.007*	*1.776*	*2.106*
Y	0.962	0.451	-1.027	0.009	-0.089
		0.419	*2.221*	*3.395*	*4.692*
ALL	0.364	3.803	-1.153	0.01	0.017
		6.567	*4.863*	*4.987*	*1.147*

Equation 2

	r2	k	rat	f1/f2	wdfa
EA	0.474	11.27	-7.655	0.613	-0.085
		3.79	*2.1*	*0.992*	*1.341*
EM	0.607	-0.2	0.111	0.183	-0.015
		0.396	*0.664*	*0.831*	*0.994*
QL	0.171	10.545	-5.856	0.176	0.002
		1.633	*0.763*	*0.178*	*0.023*
N	0.732	-0.405	0.403	0.48	-0.08
		0.135	*0.182*	*0.859*	*1.887*
NW	0.346	3.161	-1.112	0.447	0
		0.745	*1.259*	*0.474*	*0.003*
SE	0.238	2.426	-1.449	0.318	0.007
		0.949	*0.515*	*0.678*	*0.211*
SW	0.383	-0.149	1.074	0.289	-0.003
		0.083	*0.696*	*1.004*	*0.135*
WM	0.929	-0.334	-0.2	0.194	-0.036
		0.943	*1.657*	*1.676*	*3.881*
Y	0.932	-1.806	-0.492	0.565	-0.106
		1.512	*0.91*	*1.926*	*4.461*
ALL	0.231	2.349	-0.902	0.495	-0.007
		3.526	*3.569*	*2.374*	*0.46*

Equation 3

	r2	k	rat	ln(f1/f2)	wdfa
EA	0.453	11.483	-6.383	1.106	-0.062
		3.635	*2.006*	*0.847*	*0.921*
EM	0.867	1.215	-0.2	1.559	0.02
		2.731	*1.513*	*3.715*	*1.47*
QL	0.3	10.793	-4.894	2.312	0.068
		2.079	*0.706*	*1.073*	*0.664*
N	0.868	3.905	-1.474	2.857	-0.019
		1.439	*0.875*	*2.77*	*0.517*
NW	0.492	4.068	-0.93	2.901	0.055
		1.247	*1.179*	*1.42*	*0.732*
SE	0.542	2.938	-0.694	1.73	0.041
		2.127	*0.353*	*2.179*	*1.41*
SW	0.439	2.684	-0.539	1.313	0.029
		0.892	*0.242*	*1.306*	*0.869*
WM	0.926	0.529	-0.33	0.665	-0.025
		0.83	*1.788*	*1.547*	*1.596*
Y	0.963	0.433	-0.832	1.999	-0.078
		0.407	*1.948*	*3.437*	*3.606*
ALL	0.343	4.132	-1.099	2.204	0.031
		6.697	*4.601*	*4.613*	*1.723*

Equation 4

	r2	k	rat	dfq	dfa
EA	0.505	10.974	-6.384	0.004	-0.066
		4.243	*2.303*	*0.828*	*1.23*
EM	0.878	0.97	-0.215	0.007	0.01
		2.39	*1.64*	*3.742*	*0.774*
QL	0.303	10.37	-4.766	0.01	0.056
		2.066	*0.704*	*1.066*	*0.619*
N	0.896	4.482	-2.344	0.013	-0.04
		1.781	*1.46*	*3.126*	*1.189*
NW	0.494	3.862	-1.109	0.012	0.034
		1.171	*1.338*	*1.376*	*0.448*
SE	0.568	2.35	-0.18	0.008	0.035
		1.665	*0.09*	*2.276*	*1.211*
SW	0.545	2.895	-0.848	0.007	0.028
		1.165	*0.46*	*1.769*	*0.793*
WM	0.929	0.561	-0.417	0.003	-0.029
		0.94	*2.287*	*1.86*	*1.994*
Y	0.96	0.335	-1.12	0.009	-0.103
		0.297	*2.396*	*3.169*	*4.613*
ALL	0.36	3.786	-1.134	0.009	0.015
		6.283	*4.784*	*4.683*	*0.886*

Equation 5

	r2	k	rat	f1/f2	dfa
EA	0.516	10.996	-7.569	0.54	-0.103
		4.313	*2.36*	*0.917*	*1.673*
EM	0.627	-0.243	0.119	0.156	-0.02
		0.496	*0.733*	*0.72*	*1.169*
QL	0.174	11.238	-6.719	0.058	-0.018
		1.892	*0.926*	*0.068*	*0.164*
N	0.755	-0.454	0.273	0.432	-0.097
		0.158	*0.133*	*0.811*	*2.111*
NW	0.349	3.117	-1.066	0.349	-0.014
		0.736	*1.246*	*0.362*	*0.16*
SE	0.232	2.686	-1.715	0.252	0.001
		1.099	*0.626*	*0.64*	*0.032*
SW	0.39	-0.298	1.211	0.252	-0.009
		0.169	*0.824*	*0.886*	*0.303*
WM	0.925	-0.371	-0.235	0.203	-0.04
		1.007	*1.949*	*1.71*	*3.706*
Y	0.933	-1.9	-0.616	0.576	-0.122
		1.602	*1.172*	*1.906*	*4.62*
ALL	0.235	2.337	-0.868	0.436	-0.016
		3.631	*3.638*	*2.066*	*0.84*

Equation 6

	r2	k	rat	ln(f1/f2)	dfa
EA	0.49	11.271	-6.525	0.904	-0.084
		4.016	*2.262*	*0.696*	*1.166*
EM	0.853	1.202	-0.178	1.492	0.02
		2.333	*1.277*	*3.243*	*1.17*
QL	0.278	11.567	-5.902	2.102	0.057
		2.328	*0.884*	*0.931*	*0.489*
N	0.874	3.545	-1.344	2.665	-0.031
		1.343	*0.846*	*2.631*	*0.746*
NW	0.476	3.971	-0.885	2.761	0.052
		1.182	*1.113*	*1.274*	*0.68*
SE	0.501	3.202	-0.992	1.618	0.041
		2.263	*0.494*	*1.92*	*1.167*
SW	0.406	1.757	0.166	0.994	0.016
		0.692	*0.08*	*0.993*	*0.331*
WM	0.924	0.559	-0.365	0.709	-0.027
		0.874	*2.132*	*1.698*	*1.637*
Y	0.962	0.34	-0.919	1.972	-0.069
		0.31	*2.183*	*3.303*	*3.643*
ALL	0.334	4.103	-1.07	2.069	0.028
		6.283	*4.47*	*4.208*	*1.344*